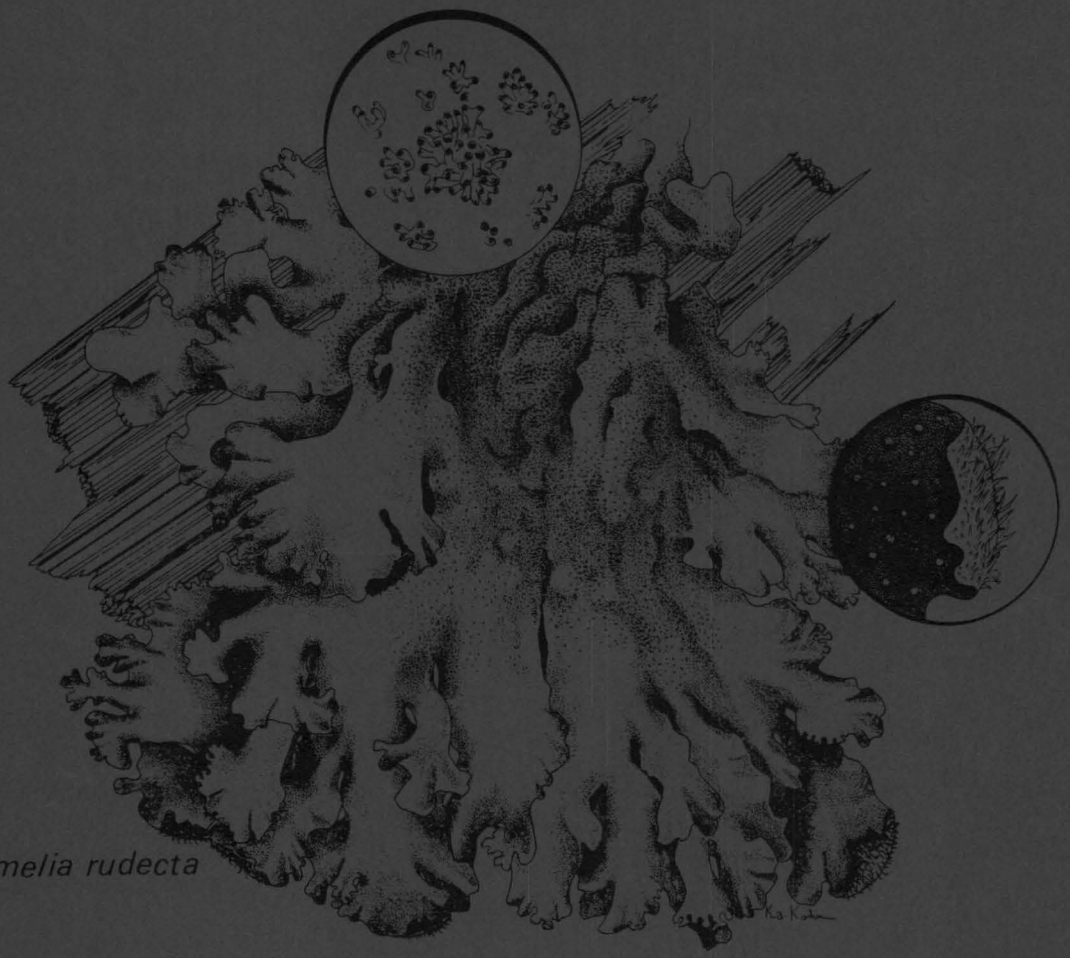
LICHENS AND AIR QUALITY IN ST. CROIX NATIONAL SCENIC RIVERWAY

FINAL REPORT

Supported by U.S. National Park Service
USDI / PX 6000-0-0317
USDI / PX 6590-8-0179



Parmelia rudecta

CLIFFORD M. WETMORE
PLANT BIOLOGY DEPARTMENT
UNIVERSITY OF MINNESOTA
ST. PAUL, MN 55108

JUNE 1991

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IN

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Final Report

National Park Service

Contract USDI/PX6590-8-0179
and
Contract USDI/PX6000-0-0317

St. Coix National Scenic Riverway
and
National Park Service
Midwest Regional Office
1707 Jackson Street
Omaha, Nebraska 68102

by

Clifford M. Wetmore
Botany Department
University of Minnesota
St. Paul, Minnesota 55108

June, 1991

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ABSTRACT

This study was to evaluate the lichen flora of St. Croix National Riverway (SACN) with respect to the air quality. Part of SACN is along the border of Minnesota and Wisconsin and the headwaters are entirely within Wisconsin. Parts of the lower SACN are downwind and near several pollution sources, including the metropolitan area of Minneapolis and St. Paul. Lichens are good indicators of air quality and this project uses lichens as air quality indicators.

Field work was done in 1988 and 1990 when 2327 collections were made at 77 localities. At some localities additional material of Parmelia rudecta was collected for chemical analysis. While collecting at each locality observations were made about the general health of the lichens.

The species list includes 265 species collected for this study and an additional 20 species reported by Fink but not found by me. There were 72 species collected only once in the study. This large number of rare species is probably due to the long length of the park. There were 18 species species with a distinctly northern distribution (from Grantsburg north). Another group of 16 species were found from just south of Taylors Falls north to the upper end of the park. A group of 10 species had a southern distribution extending from about Taylors Falls south to Prescott. There were also a number of species found only on the basaltic rocks around Taylors Falls. Most of the species were found the whole length of the park in

suitable habitats.

Some lichens were found in this study that are of special significance. Parmelia stuppea, a species on the Minnesota Threatened & Endangered list, was thought to have been eliminated from the region but was found in Minnesota at the locality four miles south of Taylors Falls. This is the first modern record for this species in Minnesota. Sticta weigelei, another rare species was found at Norway Point Landing in the cedar swamp. This species was previously known from northern Minnesota and is probably a new record for Wisconsin.

Parmelia rudecta was collected at ten localities for elemental analysis. The sulfur levels range from 620 ppm to 1580 ppm for all samples with the higher levels at the southern end of the park and also at Namekagon Dam (at the most northern end). There are no known sulfur sources near the northern end of the park and no explanation is available for this high sulfur level. The higher levels of sulfur at the southern end (Hudson to Kinnickinnic SP) might be due to industrial activity around Minneapolis/St. Paul or the King Power plant near Hudson. From Taylors Falls north sulfur levels are normal and there are no obvious trends.

PREFACE

Under contracts from the National Park Service (Contract USDI/PX6590-8-0179 and USDI/PX6000-0-0317) a lichen study was performed in The St. Croix National Scenic Riverway (SACN). This study was to survey the lichens of the park, produce a lichen flora, collect and analyze lichens for chemical contents and evaluate the lichen flora with reference to the air quality. This study is to establish baseline data for future restudy and determine the presence of any air quality problems as might be shown by the lichens at the time of the study. All work was done at the University of Minnesota with frequent consultation with personnel in the park.

The park personnel have been very helpful during the field work in providing equipment, transportation and local guidance which has contributed significantly to the success of the project. The study was made possible by funds from the National Park Service. The assistance of all of these is gratefully acknowledged.

INTRODUCTION

Lichens are composite plants composed of two different types of organisms. The lichen plant body (thallus) is made of fungi and algae living together in a symbiotic arrangement in which both partners are benefited and the composite plant body can grow in places where neither component could live alone. The thallus has no protective layer on the outside, such as the epidermis of a leaf, so the air in the thallus has free exchange with the atmosphere. Lichens are slow growing (a few millimeters per year) and remain alive for many years and so must have a habitat that is relatively undisturbed in order to survive. Lichens vary greatly in their ecological requirements but almost all of them can grow in places that only receive periodic moisture. When moisture is lacking they go dormant until the next rain or dew-fall. Some species can grow in habitats with very infrequent occurrences of moisture while others need high humidity and frequent wetting in order to survive. This difference in moisture requirements is very important in the distribution of lichens.

Lichens are known to be very sensitive to low levels of many atmospheric pollutants. Many are damaged or killed by levels of sulfur dioxide, nitrogen oxides, fluorides or ozone alone or in various combinations. Levels of sulfur dioxide as low as 13 ug/cubic meter (annual average) will cause the death of some lichens (LeBlanc et al., 1972). Other lichens are less sensitive and a few can tolerate levels of sulfur dioxide over

300 ug/cubic meter (Laundon, 1967, Trass, 1973). The algae of the thallus are the first to be damaged in areas with air pollution and the first indication of damage is discoloring and death of the algae causing bleached lobes, which quickly leads to the death of the lichen. After the lichen dies it disappears from the substrate within a few months to a year as it disintegrates and decomposes (Wetmore, 1982).

Lichens are more sensitive to air pollution when they are wet and physiologically active and are least sensitive when dry (Nash, 1973, Marsh & Nash, 1979) and are more sensitive when growing on acid substrates (Türk & Wirth, 1975).

Contrary to some published reports (Medlin, 1985) there is little evidence that most lichens are good indicators of acid precipitation. However, Sigal & Johnston (1986) have reported that one species of Umbilicaria shows visible damage due to artificial acid rain. They also report that similar symptoms were found in collections from various localities in North America. Lechowicz (1987) reported that acid rain only slightly reduced growth of Cladina stellaris but Hutchinson et al. (1986) reported that extremely acid precipitation killed or damaged some mosses and lichens. Scott & Hutchinson (1987) showed temporary reduction of photosynthesis in Cladina stellaris and C. rangiferina after artificial acid rain.

Lichens are able to accumulate chemical elements in excess of their metabolic needs depending on the levels in the substrate and the air and, since lichens are slow growing and long lived, they serve as good summarizers of the environ-

mental conditions in which they are growing. Chemical analysis of the thallus of lichens growing in areas of high fallout of certain elements will show elevated levels in the thallus. Toxic substances (such as sulfur) are also accumulated and determination of the levels of these toxic elements can provide indications of the sub-lethal but elevated levels in the air.

SACN was established in 1968 and extends over 245 miles from the head of the Namekagon River north of Cable, Wisconsin, to Prescott, Wisconsin and includes the headwaters of the St. Croix River near Gordon, Wisconsin. The lower 145 miles of the river forms the border between Minnesota and Wisconsin. The Riverway varies in width throughout its length with many areas under private ownership or control. There are five active dams on the riverway creating impoundments and several inactive dams where the river runs freely.

The vegetation changes considerably from the headwaters to the southern end. The northern parts have pine and spruce-fir forests with cedar and black ash swamps and extensive areas of second growth hardwoods (birch and aspen) while the southern end is mainly maple-elm-basswood floodplain forest. The pine include jack pine (Pinus banksiana), red pine (Pinus resinosa) and white pine (Pinus strobus) and are found on the ridges and drier localities. In the lower land along the river are white spruce (Picea glauca) and balsam fir (Abies balsamea. White cedar (Thuja occidentalis) and black ash (Fraxinus nigra) are in swampy areas in the northern half of

the riverway. In disturbed areas quaking aspen (Populus tremuloides) and white birch (Betula papyrifera) are common. The riverbottoms along the lower St. Croix have red and sugar maple (Acer rubrum and A. saccharum), elms (Ulmus spp.) and basswood (Tilia americana).

The earliest lichen records from SACN are those of Fink (1898) who collected around the rock ledges near Taylors Falls in 1896-7. He collected mainly on the rocks and reported 79 taxa. However, nomenclatural and taxonomic changes since the publication make it very difficult to compare his reports with modern species. Fortunately, most of Fink's collections are present in the herbarium at Minnesota and revised identifications are appended to this report (Appendix III) and included in the species list.

James Schuster collected in Pine County, Minn. in 1983-4 (Schuster, 1985) and some of his localities were within the riverway boundaries. The collections of Schuster were not restudied nor are they cited in this report because his collecting was too recent to be used for historical comparisons and he did not report any species that were not found in the present study.

METHODS

Field work was done in 1988 and 1990 when 2327 collections were made at 77 localities. A complete list of collection localities is given in Appendix I and are indicated on Fig. 1. In Appendix I miles are used so that locations correspond to the available USGS maps instead of converting

distances to metric units. River kilometers are not indicated on these topographic maps and could not be included. Localities for collecting were selected first to give a general coverage of the park, second, to sample all vegetational types, and third, to be in localities that should be rich in lichens. Undisturbed as well as disturbed habitats were studied. At each collection locality (about 1 ha. in size) voucher specimens of all species found were collected to record the total flora for each locality and to avoid missing different species that might appear similar in the field. At some localities additional material was collected for chemical analysis (see below). While collecting at each locality observations were made about the general health of the lichens.

Identifications were carried out at the University of Minnesota with the aid of comparison material in the herbarium and using thin layer chromatography for identification of the lichen substances where necessary. The original packet of each collection has been deposited in the University of Minnesota Herbarium and a representative set of duplicates has been sent to Smithsonian Institution.

All specimens deposited at the University of Minnesota have been entered into the herbarium computerized data base maintained there. Lists of species found at each locality are available from this data base on request.

LICHEN FLORA

The following list of lichens is based on my collections

and those reported by Fink (1898) from Taylors Falls. All species reported by Fink (1898) from Taylors Falls are also listed in Appendix III. Fink's species not found in this study are enclosed in brackets. Species found only once are indicated by "Rare". In the first columns the letters indicate the sensitivity to sulfur dioxide, if known, according to the categories proposed by Wetmore (1983): S=Sensitive, I=Intermediate, T=Tolerant. S-I is intermediate between Sensitive and Intermediate and I-T is intermediate between Intermediate and Tolerant. Species in the Sensitive category are absent when annual average levels of sulfur dioxide are above 50ug per cubic meter. The Intermediate category includes those species present between 50 and 100ug and those in the Tolerant category are present at over 100ug per cubic meter.

SPECIES LIST

Acarospora americana Magn.
Acarospora fuscata (Nyl.) Arn. Also collected by Fink.
Acarospora immersa Fink Rare
1 unidentified species of Acarospora
Acrocordia cavata (Ach.) Harris in Vezda
Acrocordia megalospora (Fink) Harris
Anaptychia palmulata (Michx.) Vain. Also collected by Fink.
Arthonia caesia (Flot.) Körb.
Arthonia patellulata Nyl.
Arthonia punctiformis Ach.
I Arthonia radiata (Pers.) Ach.
2 unidentified species of Arthopyrenia
Aspicilia caesiocinerea (Nyl. ex Malbr.) Arn.
Aspicilia cinerea (L.) Körb. Also collected by Fink
1 unidentified species of Aspicilia
Bacidia accedens (Arn.) Lett.
Bacidia inundata (Fr.) Körb.
Bacidia polychroa (Th. Fr.) Körb.
I Bacidia rubella (Hoffm.) Mass.
Bacidia sabuletorum (Schreb.) Lett.
Bacidia schweinitzii (Tuck.) Schneid. Rare
Bacidia suffusa (Fr.) Schneid.
Bacidia trachona (Ach.) Lett.

2 unidentified species of Bacidia
S Bryoria furcellata (Fr.) Brodo & Hawksw. Rare
S Bryoria trichodes (Michx.) Brodo & Hawksw. Rare
[Buellia alboatra (Hoffm.) Th. Fr. Collected by Fink.]
Buellia dialyta (Nyl.) Tuck. Rare
Buellia polyspora (Will.) Vain.
T Buellia punctata (Hoffm.) Mass. Also collected by Fink.
Buellia schaereri De Not.
Buellia stigmaea Tuck.
[Buellia stigmatea Körb. Reported by Fink.]
I Buellia stillingiana Steiner
Calicium abietinum Pers. Rare
Calicium trabinellum Ach. Rare
Caloplaca arenaria (Pers.) Müll. Arg.
S-I Caloplaca cerina (Ehrh. ex Hedw.) Th. Fr.
Caloplaca chrysophthalma Degel.
[Caloplaca cinnabarina (Ach.) Zahlbr. Collected by Fink.]
Caloplaca citrina (Hoffm.) Th. Fr.
Caloplaca feracissima Magn. Rare
S Caloplaca flavorubescens (Huds.) Laund.
Caloplaca flavovirescens (Wulf.) Dalla Torre & Sarnth.
I Caloplaca holocarpa (Hoffm.) Wade
Caloplaca microphyllina (Tuck.) Hasse
Caloplaca sarcopisoides (Körb.) Zahlbr. Rare
Caloplaca sideritis (Tuck.) Zahlbr. Also collected by Fink. Rare
I-T Caloplaca vitellinula (Nyl.) Oliv. Also collected by Fink. Rare
S-I Candelaria concolor (Dicks.) B. Stein
Candelaria fibrosa (Fr.) Müll. Arg. Also collected by Fink.
[Candelariella aurella (Hoffm.) Zahlbr. Collected by Fink.]
Candelariella efflorescens R. Harris & Buck
I Candelariella vitellina (Hoffm.) Müll. Arg.
S-I Candelariella xanthostigma (Ach.) Lett. Rare
Catapyrenium lachneum (Ach.) R. Sant. Rare
Catapyrenium tuckermanii (Rav. ex Mont.) Thoms.
Cetraria halei W. & C. Culb.
I Cetraria orbata (Nyl.) Fink Rare
Chaenotheca brunneola (Ach.) Müll. Arg.
I Chaenotheca ferruginea (Turn. ex Sm.) Mig. Rare
Chaenothecopsis debilis (Turn. & Borr. ex Sm.) Tibell
I Chrysothrix candelaris (L.) Laund. Rare
Cladina mitis (Sandst.) Hustich Also collected by Fink.
Cladina rangiferina (L.) Nyl. Also collected by Fink.
Cladonia bacillaris Nyl. Also collected by Fink.
Cladonia bacilliformis (Nyl.) Glück Rare
Cladonia botrytes (Hagen) Willd. Rare
Cladonia caespiticia (Pers.) Flörke Also collected by Fink.
[Cladonia cariosa (Ach.) Spreng. Reported by Fink.]
Cladonia chlorophaea (Flörke ex Somm.) Spreng.
Cladonia coccifera (L.) Willd. Rare

I Cladonia coniocraea (Flörke) Spreng.
Cladonia crispata (Ach.) Flot.
I Cladonia cristatella Tuck.
Cladonia cryptochlorophaea Asah.
Cladonia cylindrica (Evans) Evans Rare
Cladonia decorticata (Flörke) Spreng. Rare
Cladonia furcata (Huds.) Schrad. Rare
Cladonia gracilis (L.) Willd.
Cladonia grayi G. K. Merr. ex Sandst.
Cladonia multiformis G. K. Merr.
Cladonia parasitica (Hoffm.) Hoffm. Also collected by Fink.
Cladonia peziziformis (With.) Laundon Also collected by Fink.
Cladonia phyllophora Ehrh. ex Hoffm.
Cladonia pleurota (Flörke) Schaer.
Cladonia polycarpoides Nyl.
Cladonia pyxidata (L.) Hoffm. Also collected by Fink.
Cladonia ramulosa (With.) Laundon
Cladonia rei Schaer. Also collected by Fink.
Cladonia robbinsii Evans
Cladonia scabriuscula (Del. in Duby) Leight. Rare
Cladonia squamosa (Scop.) Hoffm. Also collected by Fink.
Cladonia symphycarpa (Ach.) Fr.
Cladonia verticillata (Hoffm.) Schaer. Also collected by Fink.
1 unidentified species of Cladonia
Coccocarpia palmicola (Spreng.) Arvid. & Galloway Rare
[Collema bachmanianum (Fink) Degel. Collected by Fink.]
Collema conglomeratum Hoffm.
Collema subflaccidum Degel. Also collected by Fink.
1 unidentified species of Collema
Cyphelium lucidum (Th. Fr.) Th. Fr. Rare
Cyphelium tigillare (Ach.) Ach. Rare
Dermatocarpon miniatum (L.) Mann Also collected by Fink.
Dimelaena oreina (Ach.) Norm. Rare
Dimerella lutea (Dicks.) Trev. Rare
Diploschistes scruposus (Schreb.) Norm. Also collected by Fink.
Endocarpon pusillum Hedw. Also collected by Fink.
Eopyrenula leucoplaca (Wallr.) R. Harris
I Evernia mesomorpha Nyl.
Gonohymenia cribellifera (Nyl.) Henss. Rare
I Graphis scripta (L.) Ach.
Haematomma elatinum (Ach.) Mass.
Heterodermia hypoleuca (Muhl.) Trev.
Heterodermia speciosa (Wulf.) Trev. Also collected by Fink.
Hyperphyscia adglutinata (Flörke) Mayrh. & Poelt Rare
Hyperphyscia syncolla (Tuck. ex Nyl.) Kalb
Hypocenomyce anthracophila (Nyl.) P. James & G. Schneid.
Hypocenomyce friesii (Ach. in Lilj.) P. James & G. Schneid.
I Hypocenomyce scalaris (Ach. in Lilj.) Choisy
Hypogymnia physodes (L.) Nyl.
Imshaugia placorodia (Ach.) S. F. Meyer

Julella fallaciosa (Stizenb. ex Arn.) R. Harris
Lecanactis chloroconia Tuck.
Lecania nylanderiana Mass. Rare
I Lecanora allophana Nyl.
[Lecanora atra (Huds.) Ach. Collected by Fink.]
[Lecanora cenisia Ach. Reported by Fink.
I [Lecanora circumborealis Brodo & Vitik. Collected by Fink.
T Lecanora dispersa (Pers.) Somm. Also collected by Fink.
Lecanora hybocarpa (Tuck.) Brodo
Lecanora impudens Degel.
T Lecanora muralis (Schreb.) Rabenh. Also collected by Fink.
[Lecanora mutabilis Somm. Collected by Fink.]
Lecanora opiniconensis Brodo Rare
I Lecanora pallida var. rubescens Imsh. & Brodo Rare
Lecanora polytropa (Hoffm.) Rabenh.
Lecanora pulicaris (Pers.) Ach.
Lecanora strobilina (Spreng.) Kieff.
I Lecanora symmicta (Ach.) Ach.
Lecanora thysanophora Harris ined.
2 unidentified species of Lecanora
[Lecidea erratica Körb. Collected by Fink.]
Lecidea hypnorum Lib. Rare
S Lecidea nylanderi (Anzi) Th. Fr.
Lecidea plebeja Nyl.
2 unidentified species of Lecidea
Lecidella euphorea (Flörke) Hert.
Lepraria finkii (B. de Lesd. in Hue) R. Harris
[Lepraria lobificans Nyl. Collected by Fink.]
Lepraria neglecta (Nyl.) Lett. Rare
2 unidentified species of Lepraria
Leptogium arsenei Sierk Rare
Leptogium burnetiae Dodge
Leptogium byssinum (Hoffm.) Zw. ex Nyl. Rare
Leptogium cyanescens (Rabenh.) Körb. Also collected by Fink.
Leptogium saturninum (Dicks.) Nyl. Rare
S Lobaria pulmonaria (L.) Hoffm.
Lobaria quercizans Michx.
Micarea melaena (Nyl.) Hedl.
Micarea prasina Fr. Rare
1 unidentified species of Microglaena
Mycocalicium subtile (Pers.) Szat.
Nephroma helveticum Ach. Also collected by Fink.
Nephroma parile (Ach.) Ach. Rare
S-I Normandina pulchella (Borr.) Nyl. Rare
Ochrolechia arborea (Kreyer) Almb.
S Ochrolechia roselia (Müll. Arg.) Vers.
S-I Opegrapha varia Pers.
Pachyospora verrucosa (Ach.) Mass.
Pachyphiale fagicola (Hepp ex Arn.) Zw. Rare
Pannaria leucophaea (Vahl) P. Jörg. Also collected by Fink. Rare
Pannaria leucosticta (Tuck. in Darl.) Tuck. ex Nyl. Rare
Parmelia aurulenta Tuck.

Parmelia baltimorensis Gyeln. Also collected by Fink.
Parmelia bolliana Müll. Arg.
I Parmelia caperata (L.) Ach.
Parmelia conspersa (Ach.) Ach.
Parmelia crinita Ach.
Parmelia cumberlandia (Gyeln.) Hale
Parmelia flaventior Stirt.
Parmelia galbina Ach.
Parmelia hypoleucites Nyl. Also collected by Fink.
Parmelia margaritata Hue Rare
I Parmelia olivacea (L.) Ach.
Parmelia plittii Gyeln.
S [Parmelia reticulata Tayl. Collected by Fink.]
I Parmelia rudecta Ach. Also collected by Fink.
I Parmelia septentrionalis (Lynge) Ahti
Parmelia soredica Nyl.
S Parmelia squarrosa Hale
Parmelia stuppea Tayl. Rare
I-T Parmelia subargentifera Nyl.
S-I Parmelia subaurifera Nyl.
I Parmelia subrudecta Nyl.
Parmelia subtinctoria Zahlbr.
I-T Parmelia sulcata Tayl.
Parmelia taractica Kremp. Also collected by Fink.
Parmelia tasmanica Hook. f. & Tayl. Rare
Peltigera canina (L.) Willd.
Peltigera didactyla (With.) Laundon Also collected by Fink.
Peltigera elisabethae Gyeln. Also collected by Fink.
Peltigera evansiana Gyeln.
I Peltigera horizontalis (Huds.) Baumg.
Peltigera lepidophora (Nyl. ex Vain.) Bitter
Peltigera membranacea (Ach.) Nyl.
Peltigera neckeri Hepp ex Müll. Arg.
Peltigera polydactyla (Neck.) Hoffm.
Peltigera praetextata (Flörke ex Somm.) Zopf
Peltigera rufescens (Weis) Humb. Also collected by Fink.
I Pertusaria amara (Ach.) Nyl. Rare
Pertusaria consocians Dibb. Rare
Pertusaria ophthalmiza (Nyl.) Nyl. Rare
Pertusaria plittiana Erichs. Rare
Pertusaria pustulata (Ach.) Duby
Pertusaria trachythallina Erichs.
Pertusaria velata (Turn.) Nyl. Also collected by Fink.
2 unidentified species of Pertusaria
Phaeocalicium curtisii (Tuck.) Tibell
Phaeocalicium polyporaeum (Nyl.) Tibell
Phaeophyscia adiastola (Essl.) Essl. Also collected by Fink.
Phaeophyscia cernohorskyi (Nadv.) Essl. Rare
Phaeophyscia chloantha (Ach.) Moberg
Phaeophyscia ciliata (Hoffm.) Moberg
Phaeophyscia hirsuta (Meresch.) Moberg
Phaeophyscia hirtella Essl.
Phaeophyscia hispidula (Ach.) Moberg

Phaeophyscia imbricata (Vain.) Essl.
Phaeophyscia melanchra (Hue) Hale
I-T Phaeophyscia nigricans (Flörke) Moberg Rare
I Phaeophyscia orbicularis (Neck.) Moberg
Phaeophyscia pusilloides (Zahlbr.) Essl.
Phaeophyscia rubropulchra (Degel.) Moberg
I Physcia adscendens (Th. Fr.) Oliv.
I Physcia aipolia (Ehrh. ex Humb.) Fürnr.
Physcia americana G. K. Merr. in Evans & Meyrow.
Physcia caesia (Hoffm.) Fürnr. Rare
T Physcia dubia (Hoffm.) Lett. Also collected by Fink. Rare
[Physcia halei Thoms. Collected by Fink.]
I Physcia millegrana Degel.
Physcia phaea (Tuck.) Thoms. Also collected by Fink.
I Physcia stellaris (L.) Nyl.
Physcia subtilis Degel.
I Physconia detersa (Nyl.) Poelt Also collected by Fink.
Placynthiella icmalea (Ach.) Coppins & James
Placynthiella uliginosa (Schrad.) Coppins & James
Placynthium nigrum (Huds.) Gray Rare
Plagiocarpa hyalospora (Nyl.) R. Harris
Platismatia tuckermanii (Oakes) W. & C. Culb.
Porpidia albocaerulescens (Wulf.) Hert. & Knoph Also collected by Fink.
Porpidia crustulata (Ach.) Hert. & Knoph
Psilolechia lucida (Ach.) Choisy Rare
Psora russellii (Tuck.) A. Schneid.
[Psorula rufonigra (Tuck.) G. Schneid. Collected by Fink.]
Pyxine sorediata (Ach.) Mont. Also collected by Fink.
S Ramalina americana Hale
Ramalina intermedia (Del. ex Nyl.) Nyl. Also collected by Fink.
Ramalina unifolia Thoms. Rare
Rhizocarpon grande (Flörke ex Flot.) Arn. Also collected by Fink.
[Rhizocarpon plicatile (Leight.) A. L. Sm. Collected by Fink.]
Rinodina arenaria (Hepp) Th. Fr. Rare
Rinodina dakotensis Magn.
Rinodina subminuta Magn. Rare
Rinodina verrucosa Sheard ined.
Sarcogyne regularis Körb.
I Scoliciosporum chlorococcum (Graewe ex Stenh.) Vezda
Spilonema revertens Nyl.
Stenocybe pullatula (Ach.) B. Stein
[Stereocaulon paschale (L.) Hoffm. Collected by Fink.]
Stereocaulon saxatile Magn. Rare
Sticta weigelei (Ach.) Vain. Rare
Strangospora pinicola (Mass.) Körb. Rare
Strigula stigmatella (Ach.) R. Harris
Strigula submuriformis (R. Harris) R. Harris
[Thelocarpon laureri (Flot.) Nyl. Collected by Fink.]
[Trapelia coarctata (Sm.) Choisy in Werner Collected by Fink.]

Trapelia involuta (Tayl.) Hert. Rare
Trapelia placodioides Coppins & James
Trapeliopsis flexuosa (Fr.) Coppins & James
Trapeliopsis granulosa (Hoffm.) Lumbsch.
Trapeliopsis viridescens (Schrad.) Coppins & James Rare
Umbilicaria mammulata (Ach.) Tuck. Also collected by Fink. Rare
S-I Usnea hirta (L.) Weber ex Wigg.
Usnea mutabilis Stirt. Rare
Usnea rubicunda Stirt.
S-I Usnea subfloridana Stirt.
1 unidentified species of Usnea
[Verrucaria fuscella (Turn.) Winch Collected by Fink.]
Verrucaria glaucovirens Grumm. Rare
Verrucaria margacea (Wahlenb. in Ach.) Wahlenb. Rare
Verrucaria muralis Ach. Also collected by Fink.
Verrucaria nigrescens Pers.
Verrucaria nigrescentoidea Fink Rare
Xanthoria elegans (Link) Th. Fr. Also collected by Fink. Rare
S-I Xanthoria fallax (Hepp in Arn.) Arn. Also collected by Fink.
I Xanthoria polycarpa (Hoffm.) Rieber
Xanthoria sorediata (Vain.) Poelt Rare

DISCUSSION OF FLORA

This list includes 265 species collected for this study and an additional 20 species reported by Fink (1898) but not found by me. There are also an additional 17 unidentified species, some of which are undescribed. The most common species are Candelaria concolor, Parmelia caperata, Parmelia rudecta, Xanthoria fallax, and Physconia detersa. Some of the 20 species reported by Fink (1898) but not found in this study are rare and probably were missed in the present study or may have disappeared from the park. Only one species found by Fink but not by me is in the most sensitive category for sulfur dioxide (Parmelia reticulata) so it is not likely that the absence of these few historical records alone indicates a change in air quality. Some of the species found only once are rare wherever they are found throughout their distributional

range and might be found at other localities with further searching and others may require special substrates that are rare in the park.

There were 72 species collected only once in the study. Figure 10 shows the numbers of rare species plotted by collection locality along the river. The large number of rare species is probably not due to lack of collecting since 77 localities were studied, but probably is due to the long length of the park. All vegetational types and habitats were sampled several times throughout the lenght of the park so species requiring special substrates should have been found more than once if the substrate was not of unique occurrence. Figure 10 does not provide much useful information because different vegetation types are not taken into account and neither is occurrence of unique substrates. Many of the rare species were found on the rocks in the vicinity of Taylors Falls - the only place where these rocks occur.

The distributions of some of the species in the park show interesting patterns. There were 18 species species with a distinctly northen distribution (e.g., Cetraria halei, Evernia mesomorpha, Hypogymnia physodes, and Lobaria pulmonmaria). This group occurred from Grantsburg north. Another group of 16 species are distributed from just south of Taylors Falls north to the upper end of the park. A group of 10 species had a southern distribution extending from about Taylors Falls south to Prescott (e.g., Caloplaca citrina, Caloplaca microphyllina, Hyperphyscia syncolla, and Cladonia symphycarpa). However,

most of the species were found the whole length of the park in suitable habitats (e.g., Caloplaca cerina, Caloplaca holocarpa, Candelaria concolor, Cladonia chlorophaea, Parmelia rudecta, Physconia detersa, and Phaeophyscia rubropulchra). There were also a number of species found only on the basaltic rocks around Taylors Falls. Rock ledges were not abundant along the river and this may explain the distribution of some of the species requiring rock substrates. Figure 11 shows the number of species per locality along the river. These numbers alone (without consideration of vegetation type) probably do not indicate much. There is a slight trend toward increasing numbers of species in the north but there is no peak in numbers of species near Taylors Falls that cannot be explained by the unusual substrates available there and the extra rare species found on the rocks.

The break in the distributions of some of the lichens near Taylors Falls corresponds with the transition zone between the prairie-forest and the boreal forest described and called the "tension zone" by Curtis (1959). This transition in the lichens is less real when considering the whole North American distribution rather than only looking at the distributions of lichens in SACN. Many of the lichens only found north of this transition zone have North American distributions extending further south and, several of the species only found south of the zone in the park extend further north when considering the whole North American distribution of the species. This may be due to the fact that

the lichens occupy microhabitats rather than the larger habitats to which the vascular plants respond.

Some lichens were found in this study that are of special significance. Parmelia stuppea is on the Minnesota Threatened & Endangered list (Wetmore, 1988) and was thought to have been eliminated from the region. However, it was found in Minnesota at the locality four miles south of Taylors Falls. Sticta weigelei, another rare species, was found at Norway Point Landing in the cedar swamp. This species was previously known from northern Minnesota but is probably a new record for Wisconsin.

In summary, the lichen flora is diverse for this area and includes many species known to be quite sensitive to sulfur dioxide. There were no cases where lichens sensitive to sulfur dioxide were observed to be damaged or killed. All species normally found fertile were also fertile in the park. These observations indicate that there is no air quality degradation in the park due to sulfur dioxide that causes observable damage to the lichen flora.

Another way of analyzing the lichen flora of an area is to study the distributions of the sensitive species within the park to look for voids in the distributions that might be caused by air pollution. Showman (1975) has described and used this technique in assessing sulfur dioxide levels around a power plant in Ohio. Only the very common species have meaning with such a technique since the rare species may be absent due to other factors.

Several of the lichens in the park are in the sensitive category to sulfur dioxide according to the list presented in Wetmore (1983). Species in the most sensitive category are usually absent when sulfur dioxide levels are above 50ug per cubic meter average annual concentrations. The species that occur in the park in the most sensitive category are as follows.

Bryoria furcellata (Fr.) Brodo & Hawksw.
Bryoria trichodes (Michx.) Brodo & Hawksw.
Caloplaca flavorubescens (Huds.) Laund.
Lecidea nylanderi (Anzi) Th. Fr.
Lobaria pulmonaria (L.) Hoffm.
Ochrolechia rosella (Müll. Arg.) Vers.
Parmelia squarrosa Hale
Ramalina americana Hale

The distributions of these species are mapped in Fig. 2-9. Although some of these species are not found at all localities and many are not common, there is no indication that the voids in the distributions are due to poor air quality. Some of the localities where collections were made do not have suitable habitats or substrates for some of these species or their distributional ranges do not extend the whole length of the park. This last is especially true for Lobaria pulmonaria that has a distinctly northern distribution in the park and in North America. Ramalina americana, on the other hand, has a North American distribution that extends much further south (into northern Iowa) but was found in SACN only in the northern localities.

ELEMENTAL ANALYSIS

An important method of assessing the effects of air

quality is by examining the elemental content of the lichens (Nieboer et al, 1972, 1977, 1978; Erdman & Gough, 1977; Puckett & Finegan, 1980; Nash & Sommerfeld, 1981). Elevated but sublethal levels of sulfur or other elements might indicate incipient damaging conditions.

METHODS

Samples of one species were collected in spunbound olefin bags at various localities in different parts of the park for laboratory analysis. Only Parmelia rudecta was abundant enough at all localities for analysis and was collected from trees. This species was selected because it is locally present in abundance even though it is fairly difficult to clean.

Ten localities were selected for elemental analysis and are indicated on the map of collection localities (Fig. 1). These localities are (from north to south): Namekagon Dam at NE end of Namekagon River, Springbrook along Namekagon River, McKenzie Creek along Namekagon River 7 miles NW of Trego, Gordon Dam at northern end of St. Croix River, Riverside near highway 35 bridge, Johns Landing at NE end of St. Croix State Park (Minn.), O Landing 4 miles east of Rush City, Minn., Taylors Falls on island in St. Croix River 3 miles S of Taylors Falls, North of Hudson at north end of town, Kinnickinnic State Park north of Prescott. Ten to 20 grams of Parmelia rudecta were collected at each locality.

Lichens were air dried and cleaned of all bark and detritis under a dissecting microscope but thalli were not washed. Three samples of each collection were submitted for

analysis. Some replicates of each species were ground before being divided for analysis and are so marked in the tables. Analysis was done for sulfur and multi-element analysis by the Research Analytical Laboratory at the University of Minnesota. In the sulfur analysis a ground and pelleted 100-150 mg sample was prepared for total sulfur by dry combustion and measurement of evolved sulfur dioxide on a LECO Sulfur Determinator, model no. SC-132, by infra red absorption. Multi-element determination for Ca, Mg, Na, K, P, Fe, Mn, Al, Cu, Zn, Cd, Cr, Ni, Pb, and B were determined simultaneously by Inductively Coupled Plasma (ICP) Atomic Emission Spectrometry. For the ICP one gram of dried plant material was dry ashed in a 20 ml high form silica crucible at 485 degrees Celsius for 10-12 hrs. Crucibles were covered during the ashing as a precaution against contamination. The dry ash was boiled in 2N HCl to improve the recovery of Fe, Al and Cr and followed by transfer of the supernatant to 7 ml plastic disposable tubes for direct determination by ICP.

RESULTS AND DISCUSSION

Table 1 gives the results of the analyses for all three replicates arranged by locality from north to south. Table 2 gives the means and standard deviations for each set of replicates. All of the reported values are above the lower detection limits of the instruments.

All of the levels found in the SACN lichens are within typical limits for similar lichens, however, there are some values that are unusually high at certain localities.

Table 1. Analysis of *Parmelia rudecta* in St. Croix NSR
Values in ppm of thallus dry weight

P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
797	2433	63861	444	561	416	21.7	72.4	101.3	4.2	2.9	8.9	0.8	1.1	2.4	1475	Namecagon Dam
879	2526	70444	501	691	632	26.4	78.1	117.6	4.5	3.4	12.0	1.3	1.4	2.3	1460	Namecagon Dam
801	2531	63629	491	666	636	24.9	77.2	112.0	4.2	3.2	11.7	1.6	1.0	2.1	1430	Namecagon Dam
485	1979	117471	410	515	230	23.7	23.9	15.4	3.7	1.7	14.0	0.8	0.5	0.6	680	Springbrook @
522	1969	118041	413	510	252	24.5	22.7	15.2	3.8	1.6	12.7	0.7	0.5	0.5	620	Springbrook @
540	2076	113338	433	534	252	22.7	24.0	15.3	3.8	1.7	16.3	1.0	1.0	0.6	870	Springbrook @
862	2750	51966	993	709	728	19.5	23.6	17.3	3.3	2.1	11.3	1.4	0.9	0.3	950	McKenzie Creek
991	2769	81061	908	714	626	19.4	23.4	17.2	3.4	2.0	6.8	0.6	1.1	0.3	920	McKenzie Creek
826	2711	43299	873	643	699	19.9	24.8	19.5	3.2	1.9	8.0	0.9	1.2	0.3	1010	McKenzie Creek
548	3212	47289	736	779	910	27.1	45.5	25.7	3.5	3.1	21.8	1.0	1.2	0.8	790	Gordon Dam
487	2759	91388	679	823	785	31.5	35.5	20.0	3.3	3.4	23.8	1.6	1.1	0.7	860	Gordon Dam
365	2363	93126	668	818	693	29.9	35.8	20.5	3.0	3.0	22.4	1.3	1.3	0.6	830	Gordon Dam
370	1454	135594	443	710	487	28.0	12.1	18.0	5.2	1.8	47.3	1.7	1.7	0.8	760	Riverside @
383	1442	133978	438	708	477	29.8	12.0	18.8	5.1	1.8	47.0	1.8	1.4	0.5	630	Riverside @
343	1358	140673	409	711	428	27.7	11.7	18.1	4.5	1.7	51.5	1.9	1.3	0.6	900	Riverside @
491	3253	45696	1089	899	907	29.2	28.5	23.9	3.3	3.5	21.3	1.9	1.7	0.7	810	Johns Landing
567	3401	47437	1276	1217	1354	37.8	33.3	28.9	3.7	5.2	24.1	2.3	2.6	0.5	930	Johns Landing
531	3125	45259	1096	939	950	31.7	38.2	24.5	3.7	3.7	22.5	2.0	2.1	0.4	730	Johns Landing
1152	3103	91338	946	811	608	26.5	13.6	23.4	4.4	2.5	13.0	2.7	1.6	0.5	820	O Landing
1220	3235	91112	1044	861	749	32.8	14.9	25.3	5.6	3.0	14.1	1.9	2.1	0.3	960	O Landing
1117	2998	102456	985	881	737	29.6	14.6	25.1	5.1	2.5	10.4	2.0	1.5	0.4	1010	O Landing
754	2174	131224	365	1079	240	24.0	18.7	27.0	2.9	1.1	9.9	1.2	0.8	0.7	1130	Taylors Falls @
756	2232	131787	374	1116	260	23.7	18.6	28.5	2.9	1.1	10.0	1.1	0.7	0.7	1080	Taylors Falls @
735	2214	126013	381	1067	286	24.2	19.1	27.3	3.0	1.1	8.3	1.2	0.8	0.6	1190	Taylors Falls @
1565	3149	88219	928	763	443	27.0	26.5	30.0	3.9	1.6	11.1	1.6	1.0	0.6	1280	N. of Hudson
1487	3280	74343	969	671	461	28.5	27.2	30.0	3.6	1.4	10.2	1.0	0.9	0.5	1280	N. of Hudson
1445	3208	85198	927	764	471	27.4	25.7	28.9	3.6	1.4	13.9	1.6	1.0	0.5	1330	N. of Hudson
2098	3975	64196	721	641	458	34.0	29.7	35.4	3.8	1.4	10.4	1.0	1.0	0.7	1530	Kinnickinnic SP
1826	3544	75359	685	705	453	32.3	28.2	31.4	3.7	1.4	12.4	1.1	1.1	0.7	1530	Kinnickinnic SP
1853	3645	66728	697	672	468	34.9	28.7	32.7	3.6	1.6	11.0	1.7	0.9	0.6	1580	Kinnickinnic SP

@ = ground before dividing into replicates

Table 2. Summary of Analysis *Parmelia rudecta* in St. Croix NSR
Values in ppm of thallus dry weight

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	826	2497	65978	479	640	562	24.3	75.9	110.3	4.3	3.2	10.9	1.2	1.2	2.2	1455	Namecagon Dam
Std. dev.	46	55	3869	30	69	126	2.4	3.1	8.3	0.2	0.2	1.7	0.4	0.2	0.1	23	Namecagon Dam
Mean	516	2008	116283	419	520	245	23.6	23.5	15.3	3.8	1.7	14.3	0.8	0.7	0.6	723	Springbrook @
Std. dev.	28	59	2567	13	13	13	0.9	0.7	0.1	<.1	0.1	1.8	0.2	0.3	0.1	131	Springbrook @
Mean	893	2743	58775	925	689	684	19.6	23.9	18.0	3.3	2.0	8.7	1.0	1.1	0.3	960	McKenzie Creek
Std. dev.	87	30	19780	62	40	53	0.2	0.8	1.3	0.1	0.1	2.3	0.4	0.1	<.1	46	McKenzie Creek
Mean	467	2778	77268	694	807	796	29.5	38.9	22.1	3.3	3.2	22.7	1.3	1.2	0.7	827	Gordon Dam
Std. dev.	93	425	25977	36	24	109	2.2	5.7	3.2	0.2	0.2	1.0	0.3	0.1	0.1	35	Gordon Dam
Mean	366	1418	136748	430	710	464	28.5	11.9	18.3	4.9	1.8	48.6	1.8	1.5	0.6	763	Riverside @
Std. dev.	20	52	3494	19	1	31	1.1	0.2	0.4	0.4	0.1	2.5	0.1	0.2	0.2	135	Riverside @
Mean	530	3260	46131	1154	1019	1070	32.9	33.4	25.8	3.5	4.2	22.7	2.1	2.1	0.5	823	Johns Landing
Std. dev.	38	138	1152	106	173	246	4.4	4.9	2.7	0.2	0.9	1.4	0.2	0.5	0.2	101	Johns Landing
Mean	1163	3112	94969	991	851	698	29.6	14.4	24.6	5.0	2.7	12.5	2.2	1.7	0.4	930	O Landing
Std. dev.	52	119	6485	50	36	78	3.2	0.7	1.0	0.6	0.3	1.9	0.4	0.3	0.1	98	O Landing
Mean	748	2207	129675	373	1087	262	24.0	18.8	27.6	2.9	1.1	9.4	1.2	0.8	0.7	1133	Taylors Falls @
Std. dev.	11	30	3184	8	26	23	0.2	0.3	0.8	0.1	<.1	1.0	0.1	0.1	0.1	55	Taylors Falls @
Mean	1499	3212	82587	941	733	458	27.7	26.4	29.6	3.7	1.5	11.7	1.4	1.0	0.5	1297	N. of Hudson
Std. dev.	61	66	7297	24	53	14	0.8	0.8	0.6	0.1	0.1	1.9	0.3	<.1	<.1	29	N. of Hudson
Mean	1926	3721	68761	701	673	460	33.7	28.9	33.2	3.7	1.5	11.3	1.3	1.0	0.6	1547	Kinnickinnic SP
Std. dev.	150	225	5853	19	32	8	1.4	0.8	2.1	0.1	0.1	1.1	0.4	0.1	0.1	29	Kinnickinnic SP

@ = ground before dividing into replicates

The sulfur levels in lichens tested range from 620 to 1580 ppm for all samples and these values are near background levels for other species of lichens as cited by Solberg (1967) Erdman & Gough (1977), Nieboer et al (1977) and Puckett & Finegan (1980). Levels in some lichens may be as low as 200-300 in the arctic (Tomassini et al, 1976) while levels in polluted areas are 4300-5200 ppm (Seaward, 1973) or higher. Previous analyses of Parmelia rudecta showed somewhat higher levels of sulfur. In Cuyahoga Valley NRA sulfur levels were 1320-2420 ppm and in Delaware Water Gap NRA 1150-1800 ppm. The levels in SACN were generally lower at most localities. The sulfur levels in this study are higher at the southern end of the park but also at Namekagon Dam (at the most northern end). There are no known sulfur sources near the northern end of the park and no explanation is available for this high sulfur level. The higher levels of sulfur at the southern end (Hudson to Kinnickinnic SP) might be due to industrial activity to the west (Minneapolis/St. Paul) or the refinery. The King Power plant near Hudson has a very tall smokestack and may not be contributing to the pollution in its immediate vicinity but may be a factor further douw river. From Taylors Falls north all sulfur levels are low and there are no obvious trends.

Of the other elements, manganese, zinc and cadmium are much higher at Namekagon Dam, iron and magnesium seem to be high at Johns Landing, and lead is quite high at Riverside. None of these elevated levels can be explained by observed local sources. There seems to be no trends or anomalous levels

in any other elements or localities.

These tables indicate that there are no air pollution problems in the northern part of the park except possible near Namekagon Dam. There may be a potential air quality problem south of Hudson.

CONCLUSIONS

There are no strong indications that the lichens of SACN are being damaged by air quality although pollution levels may be near the critical threshold in the southern end. The lichen flora is quite diverse throughout the park and there is no impoverishment of the lichen flora in any part of the the park. The loss of species around Taylors Falls is probably due to trampling and human activity rather than air pollution. There are numerous species in the most sensitive category to sulfur dioxide in the park and their distributions along the river only reflect normal distribution patterns. The maps of the distributions of the more sensitive species do not show any significant voids that are not due to normal ecological conditions. There is no evidence of damaged or dead lichens in any area where healthy ones are not also present. The elemental analyses do not show abnormal accumulations of polluting elements at most of the northern localities but higher sulfur levels were found at the southern end and at Namekagon Dam.

RECOMMENDATIONS

Because of the higher levels of some pollution elements in the southern end of the park and at Namekagon Dam, further

studies in these areas are needed. Additional elemental analyses should be done around Namegagon Dam to determine the reason for the higher levels of some elements. Elemental analyses should also be done from Hudson south to Prescott every 3-5 years to detect changes in pollution levels.

In future park planning and construction (including trails) the areas of cedar swamps should be preserved undisturbed to prevent loss of rare species. This is especially important at Norway Point Landing where a very rare species was found in the cedar swamp.

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APPENDIX I

Collection Localities

Collection numbers are those of Clifford Wetmore. All collections are listed in ascending order by collection number and date of collection. Distances are given according to the USGS topographic maps available. In parenthesis under the collection numbers is the locality number that was used to plot Tables 3 and 4.

Chisago County, Minn.

62585-62623 (23) Minnesota Interstate Park. Taylors Falls. Around ledges near river with hardwoods and few white pines. Sec. 30, T34N, R18W. 22 Sept. 1988.

62624-62670 (21) Four miles south of Taylors Falls just west of Franconia. In valley up from St. Croix River with elm, basswood, oak and ash. Sec. 10, T33N, R19W. 22 Sept. 1988.

62671-62700 (20) 1.5 miles NNW of Osceola, Wisc. At head of valley leading down to St. Croix River in pasture with hardwoods and stream. Sec. 16, T33N, R19W. 22 Sept. 1988.

Polk County, Wisc.

62701-62761 (24) Wisconsin Interstate Park. Around rocky knobs and cliffs near St. Croix River east of Taylors Falls with oaks, pines and rocks. Sec. 30, T34N, R18W. 28 Sept. 1988.

62762-62786 (18) At southern edge of Osceola. Along ridge and steep hillside above St. Croix River with maples, oaks and some white pine and rocks. Sec. 28, T33N, R19W. 30 Sept. 1988.

Chisago County, Minn.

62787-62811 (19) Across St. Croix River from Osceola, Wisc. On roadbank with rock outcrop and sumac. Sec. 28, T33N, R19W. 30 Sept. 1988.

Washington County, Minn.

62812-62849 (17) Three miles northeast of Scandia, half mile north of railroad bridge. On slopes above St. Croix River with oaks, maples, basswood and rock outcrops. Sec. 7, T32N, R19W. 30 Sept. 1988.

St. Croix County, Wisc.

62850-62873 (16) Across St. Croix River from Marine on St. Croix, Minn. In low area with hardwoods (white birch, basswood, oaks, maples). Sec. 6, T31N, R19W. 4 Oct. 1988.

62874-62906 (14) 5 miles southwest of Somerset. On banks of valley into St. Croix River along abandoned railroad grade with quaking aspen, oaks and white birch. Sec. 7, T30N, R19W. 4 Oct. 1988.

Washington County, Minn.

62907-62940 (15) Two miles south of Marine on St. Croix behind research lab. In ash bog along stream with ash, basswood, red maple and elm. Sec. 18, T31N, R19W. 4 Oct. 1988.

62941-62965 (12) Two miles north of Stillwater along highway 95. Along cliffs above road southeast of Arcola Trail in oaks and rocks. Sec. 14, T30N, R20W. 5 Oct. 1988.

62966-62971 (8) Three miles north of Lakeland along bank above railroad (across from Hudson, Wisc.). Around gravel bank with oaks and honey locust and on bottomland with elm and aspen. Sec. 14, T29N, R20W. 5 Oct. 1988.

St. Croix County, Wisc.

62972-62986 (9) North of Hudson at east end of Lake Mallalieu. On hillside above swamp southeast of road with elm, quaking aspen, basswood and oaks. Sec. 18, T29N, R19W. 5 Oct. 1988.

Washington County, Minn.

62987-63014 (7) Along North Point Douglas Road at north edge of Afton. In old gravel pit west of St. Marys Point with some juniper and big tooth aspen. Sec. 15, T28N, R20W. 5 Oct. 1988.

St. Croix County, Wisc.

63015-63022 (11) At wayside park along highway 35, 1.5 miles southeast of Houlton. On steep shady banks of St. Croix River below park with oaks, elm and few aspen. Sec. 35, T30N, R20W. 6 Oct. 1988.

63023-63037 (6) Across river from Afton, Minn. Along valley and ridge above St. Croix River with oaks and basswood. Sec. 23, T28N, R20W. 6 Oct. 1988.

Pierce County, Wisc.

63038-63067 (4) Four miles northeast of Prescott. Along top of gully and ridge above St. Croix River with oaks, quaking aspen and sumac. Sec. 23, T27N, R20W. 6 Oct. 1988.

63068-63084 (3) Kinnickinnic State Park. Along stream bottom with willow, boxelder, silver maple and elm. Sec. 13, T27N, R20W. 6 Oct. 1988. CHEMICAL ANALYSIS.

Polk County, Wisc.

63085-63131 (22) Island in St. Croix River 3 miles south of Taylors Falls just north of Rice Lake. Open oak woods around rock hill with bur oak, black oak, elm and silver maple near shore. Sec. 10, T33N, R19W. 11 Oct. 1988. CHEMICAL ANALYSIS.

Washington County, Minn.

63132-63164 (5) Afton State Park. East of highway along upper end of Trout Brook. In valley with elm, willow, aspen and rocks. Sec. 34, T28N, R20W. 13 Oct. 1988.

63165-63188 (2) Three miles north of Prescott, Wisc. at Control Data Park. Along ridges and hillside of valley of St. Croix River with oaks, elms and juniper. Sec. 27, T27N, R20W. 13 Oct. 1988.

63189-63206 (1) Just north of Hastings north of Point Douglas. On hillside above St. Croix River and along abandoned railroad grade with elm and oaks. Sec. 9, T26N, R20W. 13 Oct. 1988.

St. Croix County, Wisc.

63207-63233 (10) Just north of Hudson in deep valley of stream into St. Croix River. Along hillside and valley bottom with oaks, maples and aspens. Sec. 12, T29N, R20W. 18 Oct. 1988. CHEMICAL ANALYSIS.

63234-63258 (13) Near Apple River Falls and hydroplant 11 miles north of Hudson. Around ridge and down to Apple River on steep hillside with oaks, aspens, white birch and white pines. Sec. 21, T31N, R19W. 18 Oct. 1988.

Bayfield County, Wisc.

66221-66276 (71) Namekagon Dam area at Lake Namekagon (7 mi NE of Cable). At west end of lake near shore with sugar maple and basswood and some yellow birch and pines. Sec. 8, T43N, R6W. 5 July 1990. CHEMICAL ANALYSIS.

66277-66313 (70) South of Lake Tahkodah along Namegagon River (4 mi NE of Cable). In lowland with alder, balsam fir and quaking aspen. Sec. 3, T43N, R7W. 6 July 1990.

66314-66349 (69) 1 mile east of Cable. On rock outcrop along Namekagon River with some white pine and white spruce in lowland. Sec. 20, T43N, R7W. 6 July 1990.

66350-66372 (68) 1.5 miles southwest of Cable along Namekagon River. In ash bog with some balsam fir. Sec. 24, T43N, R8W. 7 July 1990.

66373-66402 0.5 mile north of county line on Namekagon River north of Pacwawong Lake. In ash bog with Thuja and balsam

(67) fir. Sec. 35, T43N, R8W. 7 July 1990.

Sawyer County, Wisc.

66403-66439 (66) 1 mile southwest of Pacwawong Lake. Along river with red maple, black ash and balsam fir. Sec. 9, T42N, R8W. 7 July 1990

66440-66489 (65) 2 miles north of Phipps Flowage (6.5 mi NE of Hayward). In red maple and balsam fir area below steep hills. Sec. 29, T42N, R8W. 8 July 1990.

66490-66536 (64) Just south of Phipps Dam along Namekagon River (4 miles NE of Hayward). In area by river with balsam fir, red maple and black ash. Sec. 6, T41N, R8W. 8 July 1990.

66537-66569 (63) 2 miles southwest of Hayward Dam near state nursery. On slope above river with big tooth aspen and jack pine. Sec. 33, T41N, R9W. 9 July 1990.

66570-66604 (62) Just east of county line on Namekagon River 4 miles southwest of Hayward. On point with black ash and few elm. Sec. 7, T40N, R9W. 9 July 1990.

Washburn County, Wisc.

66605-66641 (61) Just west of county road E crossing of Namekagon River (6 miles WSW of Hayward). On hillside with red pine, quaking aspen and oaks, maple and birch. Sec. 34, T41N, R10W. 10 July 1990.

66642-66668 (60) 0.5 miles west of Brinkman Lake along Namegacon River above Tranus Creek (3 miles NE of Springbrook). On upland with jack pine, red oak, bur oak and quaking aspen. Sec. 32, T41N, R10W. 10 July 1990.

66669-66695 (59) 1 mile west of Springbrook along Namegagon River. In low area with black ash, nettle and skunk cabbage. Sec. 15, T40N, R11W. 10 July 1990. CHEMICAL ANALYSIS.

66696-66726 (58) 1.5 miles northeast of Earl along Namekagon River. In jack pine plantation with some red oak and quaking aspen and in logged area back from river. Sec. 20, T40N, R11W. 10 July 1990.

66727-66762 (57) Northwest edge of Earl opposite campground along Namekagon River. On ridge with red pine, quaking aspen and some red oak. Sec. 30, T40N, R11W. 11 July 1990.

66763-66799 (56) 1.5 miles east of Trego along Namekagon River. On hillside and ridge on northeast side of river with jack pine and red oak. Sec. 36, T40N, R12W. 11 July 1990.

66800-66833 (55) West of McKenzie Creek along Namekagon River (7 miles NW of Trego). On low point with basswood and few white pine and red maple. Sec. 1, T40N, R12W. 12 July 1990.

CHEMICAL ANALYSIS.

66834- North of Island Lake along Namekagon River (9 miles NW
66871 of Trego). On ridgetop with jack pine, big tooth aspen
(54) and some white birch. Sec. 35, T41N, R13W. 12 July 1990.

66872- Whispering Pines Landing along Namekagon River (11
66891 miles northwest of Trego). In bog with black ash and
(53) basswood. Sec. 27, T41N, R13W. 12 July 1990.

66892- Half mile southeast of Pear Lake off highway 11 (12
66922 miles northwest of Trego). On ridge and hillside above
(52) Namekagon River with jack pine and quaking aspen. Sec.
17, T41N, R13W. 13 July 1990.

Burnett County, Wisc.

66923- Half mile southeast of McDowel Bridge along Namekagon
66951 River (15 miles northwest of Trego). On gentle north
(51) facing slope with red maple and white birch. Sec. 12,
T41N, R14W. 13 July 1990.

Douglas County, Wisc.

66952- Just below Gordon Dam on St. Croix River (5 miles west
66994 of Gordon). In Thuja and black ash bog near river. Sec.
(77) 36, T44N, R13W. 16 July 1990. CHEMICAL ANALYSIS.

66995- Scott Bridge on St. Croix River (7 miles west of
67036 Gordon). Along roadside in quaking aspen, white spruce
(76) and balsam fir. Sec. 35, T44N, R13W. 16 July 1990.

67037- Along railroad grade by St. Croix River southwest of
67055 Scott Bridge (17 miles east of Dairyland). In young
(75) growth of ash, alder and brush near river. Sec. 8,
T43N, R13W. 16 July 1990.

67056- At county road T and St. Croix River (5 miles east
67085 southeast of Dairyland). On steep hillside with big
(74) tooth aspen and few red oak and maple. Sec. 23, T43N,
R14W. 16 July 1990.

67086- Schoen Park on St. Croix River (5 miles south
67120 southeast of Dairyland). Near stream with white pine
(73) and quaking aspen. Sec. 33, T43N, R14W. 17 July 1990.

Burnett County, Wisc.

67121- CCC bridge over St. Croix River (7 miles south of
67143 Dairyland). In floodplain with scattered black ash,
(72) silver maple and brush. Sec. 16, T42N, R14W. 17 July
1990.

67144- Just south of Namekagon Road bridge over Namekagon
67172 River (10 miles south of Dairyland). On hill with jack
(50) pine, red pine and red oak. Sec. 33, T42N, R14W. 17
July 1990.

67173- Just south of confluence of St. Croix and Namekagon
67206 Rivers (9 miles south of Dairyland). On upland with
(49) open young red oak. Sec. 36, T42N, R15W. 17 July 1990.

67207- Riverside at highway 35 bridge (10 miles south
67241 southwest of Dairyland). On south side of St. Croix
(48) River in bog with basswood, ash and balsam fir. Sec.
33, T42N, R15W. 18 July 1990. CHEMICAL ANALYSIS.

67242- Above Pansy Landing across from Upper Tamarack River
67268 (5.5 miles northeast of Danbury). On upland with mixed
(47) forest of white pine, oaks and some balsam fir. Sec. 1,
T41N, R16W. 18 July 1990.

67269- 2 miles northeast of Danbury. On hillside above St.
67285 Croix River with red maple, red oak and few quaking
(46) aspen. Sec. 22, T41N, R16W. 18 July 1990.

67286- 3 miles west of Danbury at highway 77 bridge. In low
67316 area by St. Croix River with black ash, basswood and
(45) silver maple. Sec. 25, T41N, R17W. 18 July 1990.

Pine County, Minn.

67317- St. Croix State Park. At Johns Landing camp at
67356 northeast end of park. In ash bog west of camp with
(43) black ash and some red maple and white pine. Sec. 31,
T41N, R18W. 28 Aug. 1990. CHEMICAL ANALYSIS.

67357- St. Croix State Park. 1 mile north of St. Croix River
67387 above Sand Creek Landing. On ridge with old quaking
(41) aspen, basswood and some oaks. Sec. 24, T40N, R19W. 28
Aug. 1990.

67388- St. Croix State Park. Above main campground on ridge
67413 with jack pine, oaks and some big tooth aspen. Sec. 14,
(42) T40N, R18W. 28 Aug. 1990.

67414- Stevens Creek Access to St. Croix River at southeast
67439 corner of county. Just northeast of landing along river
(33) with basswood and silver maple. Sec. 33, T38N, R20W. 29
Aug. 1990.

Chisago County, Minn.

67440- Wild River State Park. South of Landers Landing. In
67465 ash bog back from St. Croix River. In ash bog back from
(31) river with black ash, red maple and basswood. Sec. 6,
T36N, R20W. 29 Aug. 1990.

67466- Wild River State Park. 5 miles east of Sunrise at St.
67498 Croix River. In steep gullies between road and river
(28) with basswood and sugar maple. Sec. 31, T36N, R19W &
Sec. 6, T35N, R19W. 29 Aug. 1990.

Burnett County, Wisc.

67499-67524 (44) 1 mile southwest of Sioux Portage campground (7 miles southwest of Danbury). In upland with red oak, basswood and jack pine. Sec. 4, T40N, R17W. 3 Sept. 1990.

67525-67565 (40) Norway Point Landing (13 miles west of Webster). In bog with Thuja, black ash, yellow birch and some red maple and balsam fir. Sec. 30, T40N, R18W. 3 Sept. 1990.

67566-67588 (39) Above Nelson Landing (15 miles west of Webster). In oak woods on highland with red oak and few pines. Sec. 2, T39N, R19W. 3 Sept. 1990.

67589-67624 (38) Fox Landing northwest of Grantsburg (16 miles west of Webster). In lowland near St. Croix River with ash, red maple and some basswood. Sec. 3, T39N, R19W. 4 Sept. 1990.

67625-67649 (37) At East Brook at end of Paint Mine Road (5 miles north northwest of Grantsburg). On ridge above stream with white pine, red pine, jack pine and few hardwoods. Sec. 29, T39N, R19W. 4 Sept. 1990.

67650-67686 (36) Sonderbeck Landing across St. Croix River from Snake River (5 miles west northwest of Grantsburg). In lowland with quaking aspen, white birch and brush. Sec. 31, T39N, R19W. 4 Sept. 1990.

67687-67716 (35) Sandrock Cliff Access and campground (5 miles west of Grantsburg). Around sandstone cliffs and on top with hardwoods in low areas and pines on top. Sec. 7, T38N, R19W. 4 Sept. 1990.

67717-67732 (34) Southwest of Raspberry Landing (7 miles west southwest of Grantsburg). On hillside of St. Croix River with streams, maples, oaks and some ash and basswood. Sec. 26, T38N, R20W. 5 Sept. 1990.

67733-67752 (32) County Road O Landing (4 miles east of Rush City, Minn.) In bottomland near St. Croix River with maples, ash and basswood. Sec. 20, T37N, R20W. 5 Sept. 1990. CHEMICAL ANALYSIS.

Polk County, Wisc.

67753-67784 (30) 5 miles east northeast of Harris, Minn. near St. Croix River. In open old fields and in open patches of quaking aspen at edge. Sec. 18, T36N, R20W. 5 Sept. 1990.

67785-67808 (29) Sunrise Landing 2 miles north of Sunrise, Minn. Along St. Croix River in open areas with green ash and bur oak. Sec. 32, T36N, R20W. 5 Sept. 1990.

67809- Nevers Dam Landing (1.5 miles south of Wolf Creek).
67843 Around old gravel pit near river with few elms. Sec. 9,
(27) T35N, R19W. 6 Sept. 1990.

67844- 7 miles northwest of St. Croix Falls. In small gullies
67862 up from St. Croix River with basswood, silver maple and
(26) black ash. Sec. 27, T35N, R19W. 6 Sept. 1990.

67863- 3.5 miles north of St. Croix Falls. On hillside across
67884 road from river in stand of big tooth aspen, basswood
(25) and sugar maple. Sec. 1, T34N, R19W. 6 Sept. 1990.

ST. CROIX NATIONAL SCENIC RIVERWAY
Lower St. Croix

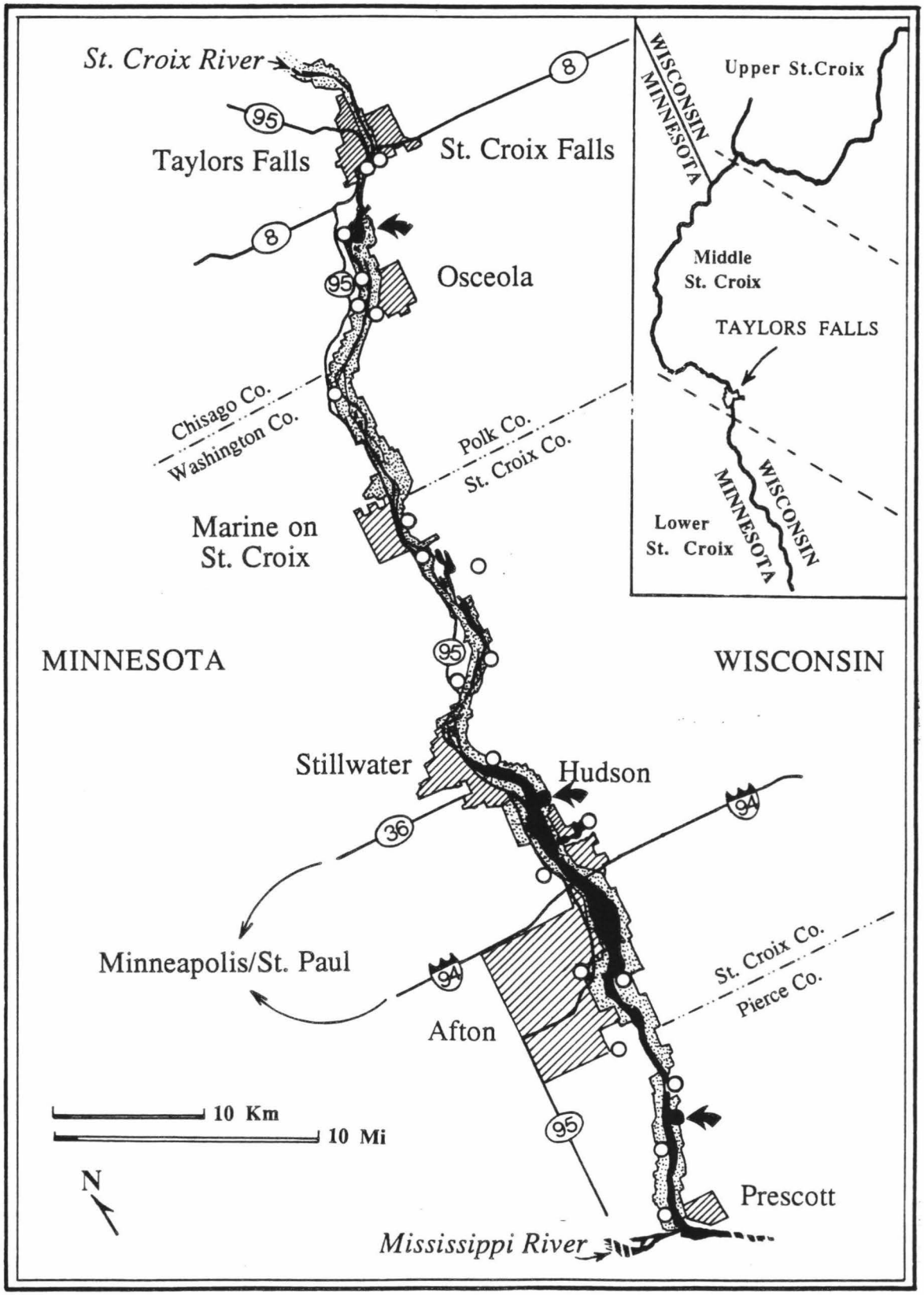

Fig. 1a. Open circles are collection localities, solid circles are elemental analysis localities.

ST. CROIX NATIONAL SCENIC RIVERWAY
Middle St. Croix

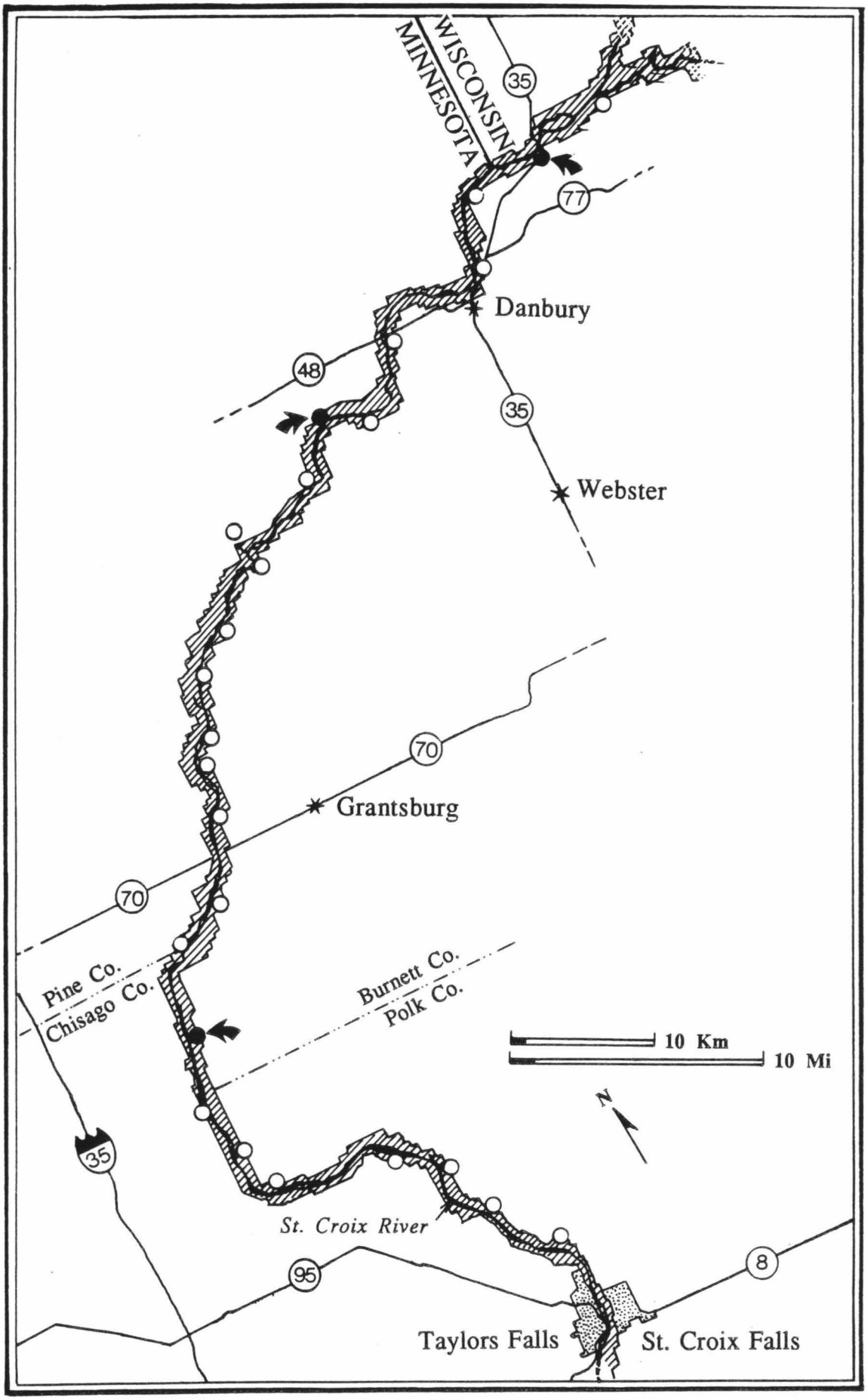

Fig. 1b. Open circles are collection localities, solid circles are elemental analysis localities.

ST. CROIX NATIONAL SCENIC RIVERWAY
Upper St. Croix

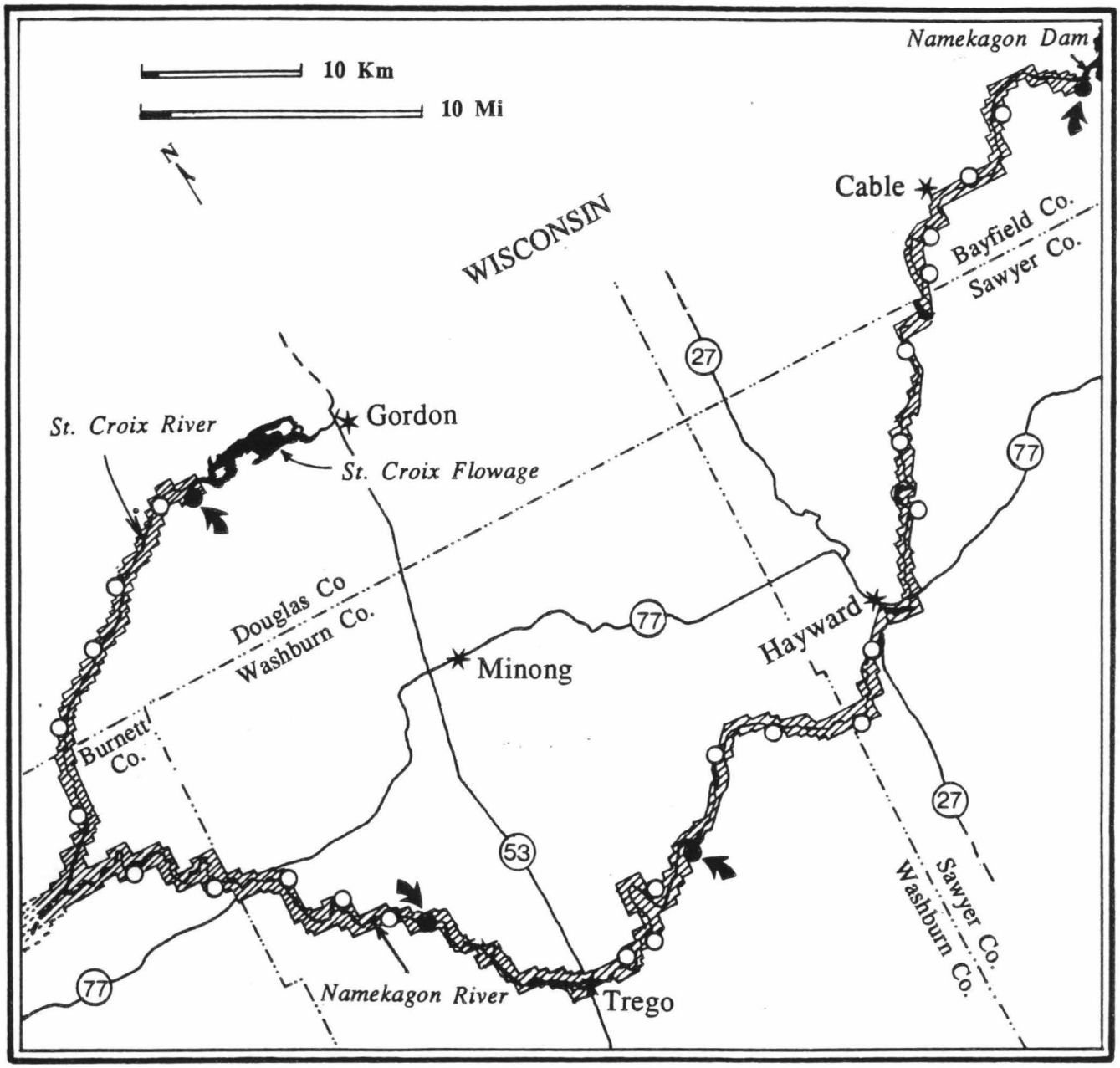

Fig. 1c. Open circles are collection localities, solid circles are elemental analysis localities.

APPENDIX II

Species Sensitive to Sulfur Dioxide

Based on the list of lichens with known sulfur dioxide sensitivity compiled from the literature, the following species in SACN fall within the Sensitive and Sensitive/-Intermediate categories as listed by Wetmore, 1983. Sensitive species (S) are those present only under 50ug sulfur dioxide per cubic meter (average annual). The intermediate category includes species present between 50ug and 100ug. The S-I group falls between the Sensitive and Intermediate categories. Open circles on the maps are localities where the species was not found and solid circles are where it was found. The species in both of these categories are mapped.

Note: Refer to text for interpretation of these maps and precautions concerning absence in parts of the park.

Fig. 2. a, b. *Bryoria furcellata* (Fr.) Brodo & Hawksw.
Fig. 3. a. *Bryoria trichodes* (Michx.) Brodo & Hawksw.
Fig. 4. a, b, c. *Caloplaca flavorubescens* (Huds.) Laund.
Fig. 5. a. *Lecidea nylanderi* (Anzi) Th. Fr.
Fig. 6. a. *Lobaria pulmonaria* (L.) Hoffm.
Fig. 7. a, b. *Ochrolechia rosella* (Müll. Arg.) Vers.
Fif. 8. a, b, c. *Parmelia squarrosa* Hale
Fig. 9. a, b. *Ramalina americana* Hale

ST. CROIX NATIONAL SCENIC RIVERWAY
Middle St. Croix

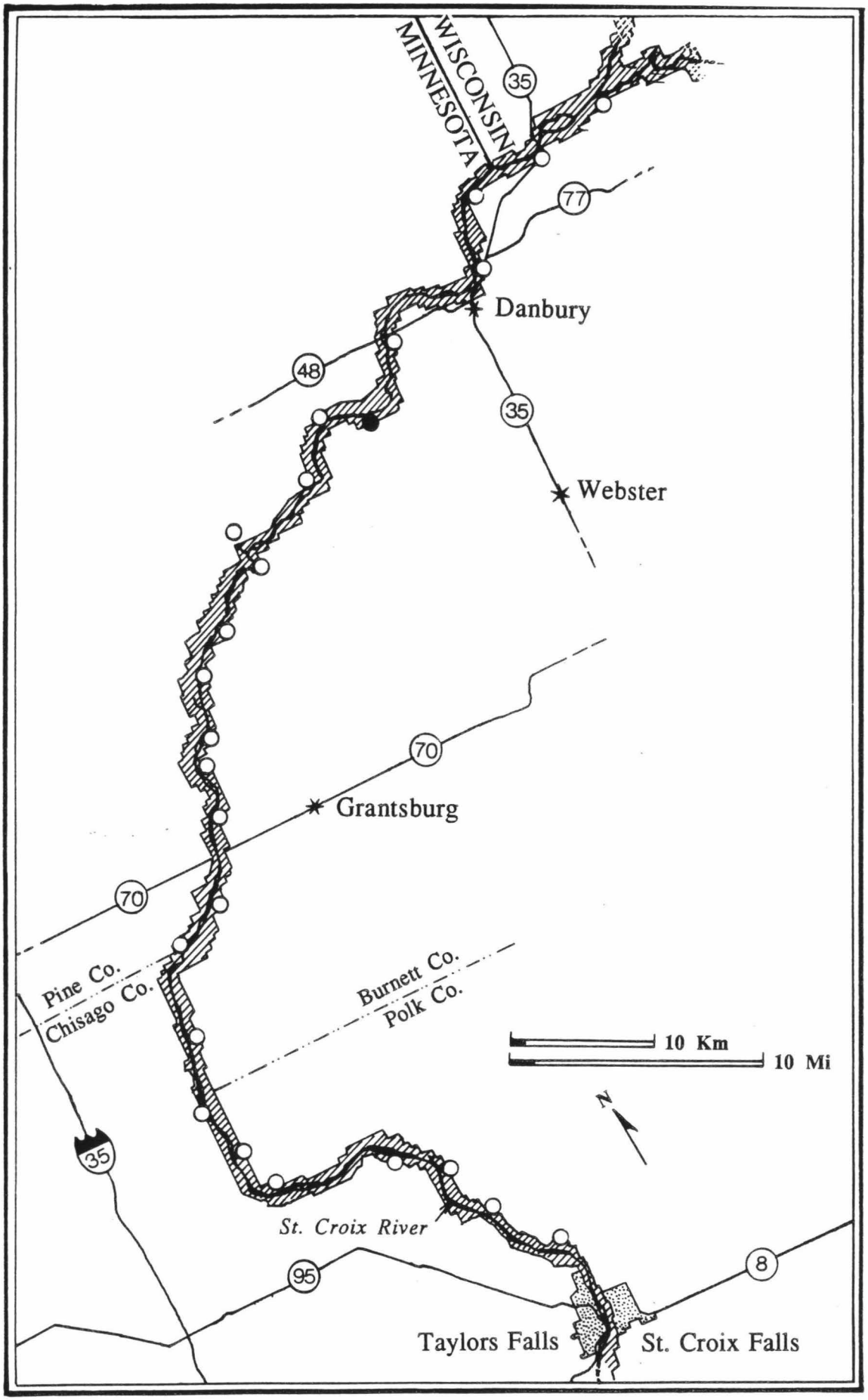

Fig. 2a. Distribution of Bryoria furcellata (1 locality).

ST. CROIX NATIONAL SCENIC RIVERWAY
Upper St. Croix

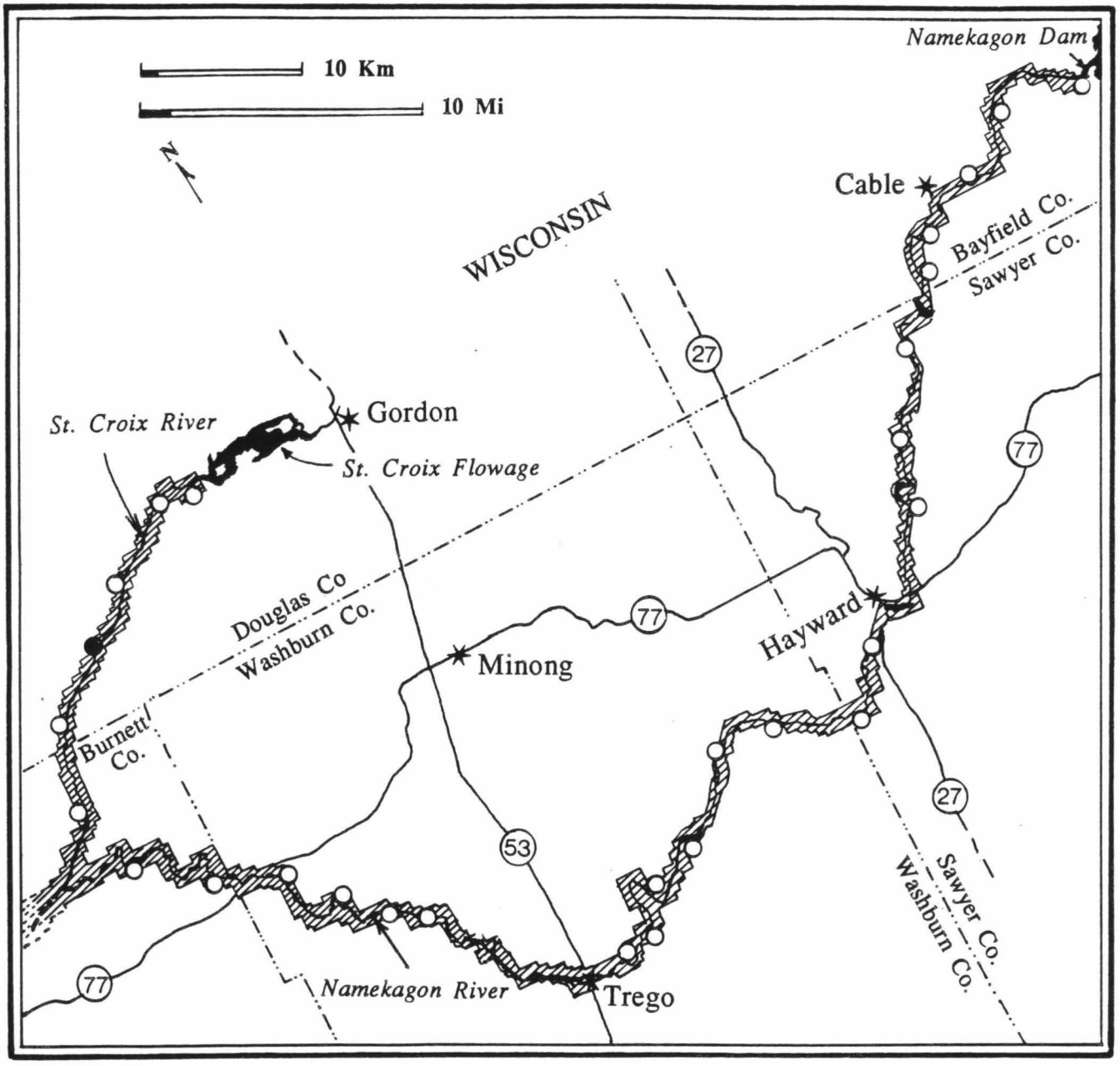

Fig. 2b. Distribution of Bryoria furcellata (1 locality).

ST. CROIX NATIONAL SCENIC RIVERWAY
Upper St. Croix

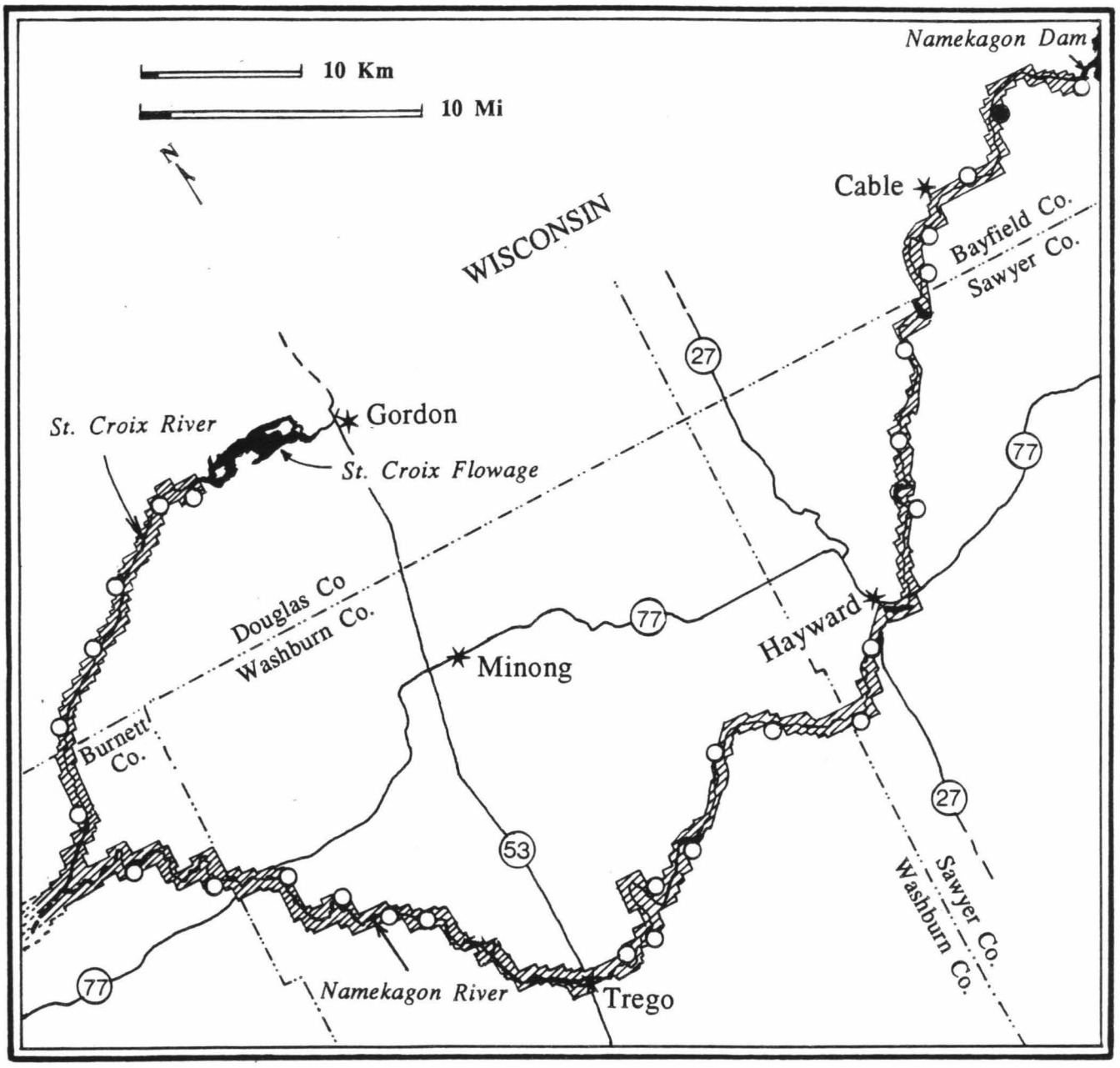

Fig. 3a. Distribution of Bryoria trichodes (1 locality).

ST. CROIX NATIONAL SCENIC RIVERWAY
Lower St. Croix

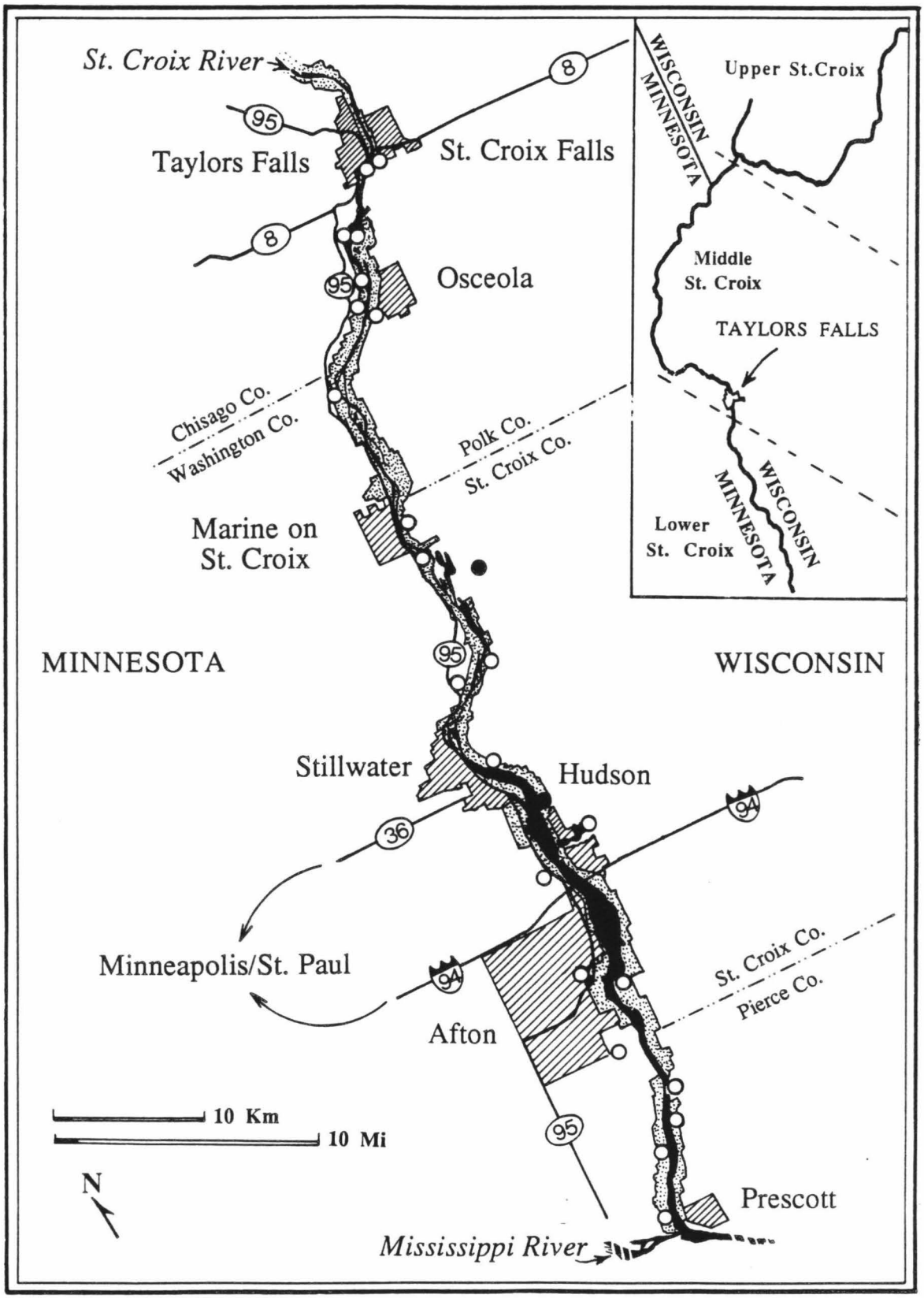

Fig. 4a. Distribution of Caloplaca flavorubescens (2 localities).

ST. CROIX NATIONAL SCENIC RIVERWAY
Middle St. Croix

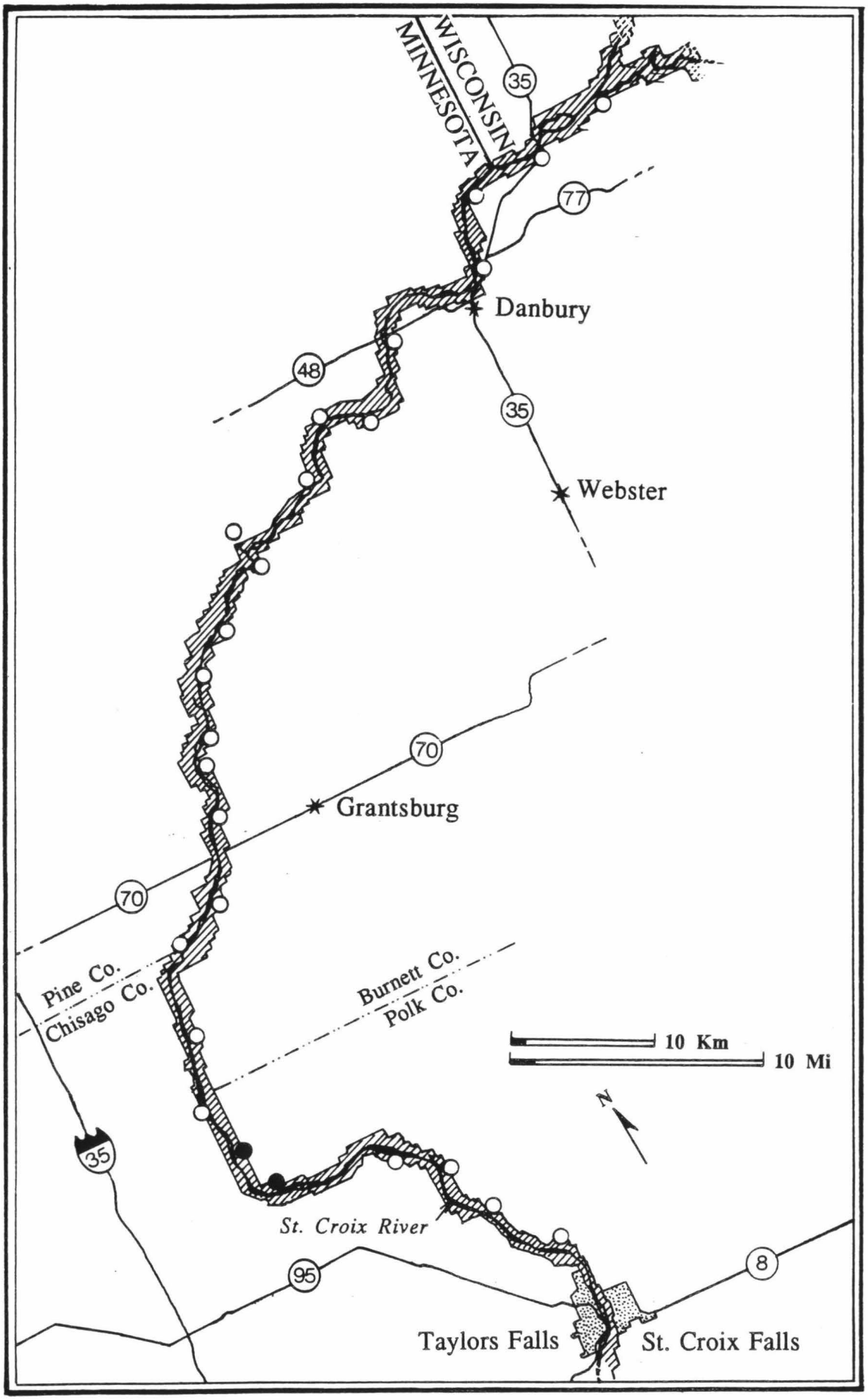

Fig. 4b. Distribution of Caloplaca flavorubescens (2 localities).

ST. CROIX NATIONAL SCENIC RIVERWAY
Upper St. Croix

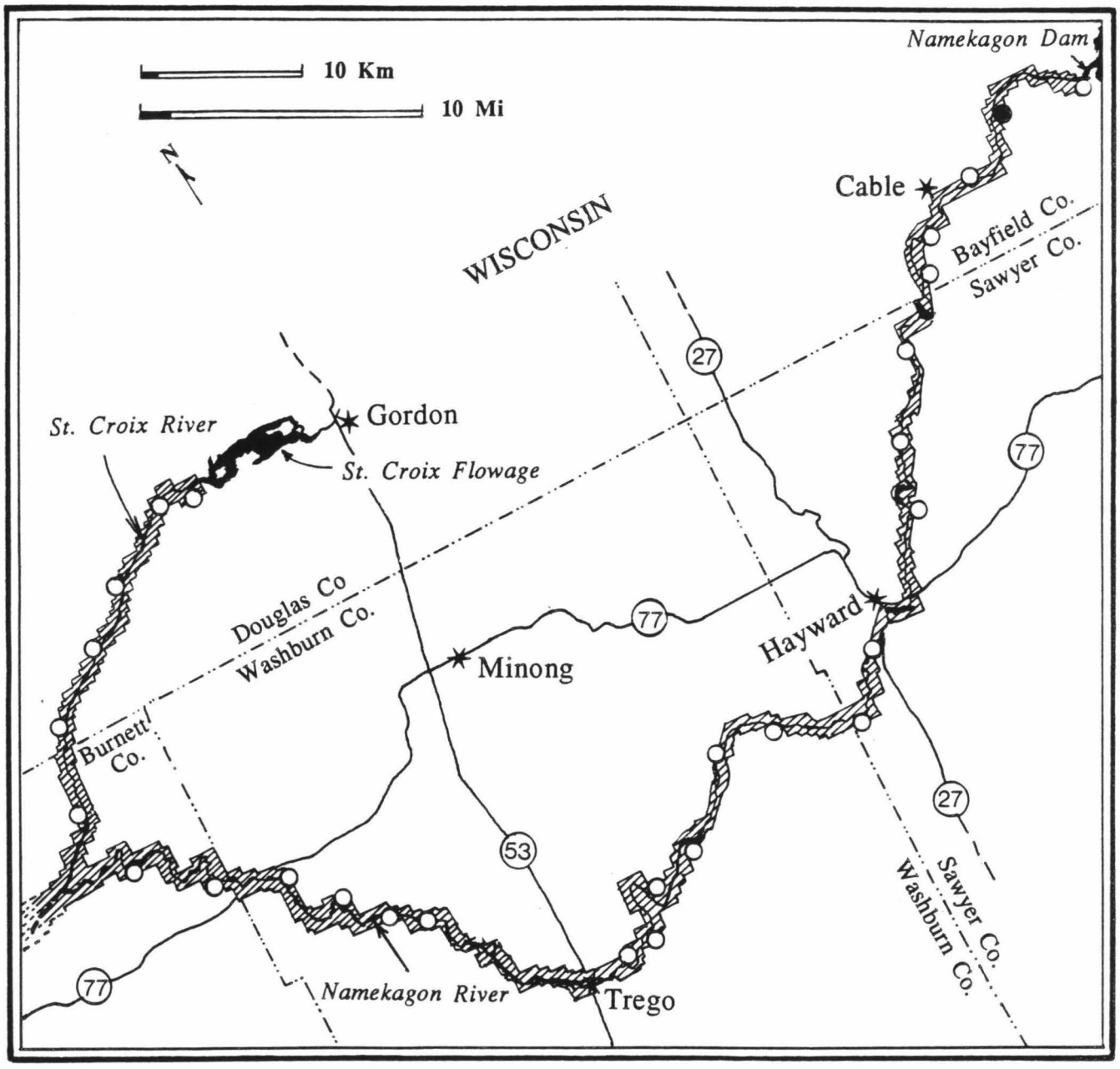

Fig. 4c. Distribution of Caloplaca flavorubescens (1 locality)

ST. CROIX NATIONAL SCENIC RIVERWAY
Upper St. Croix

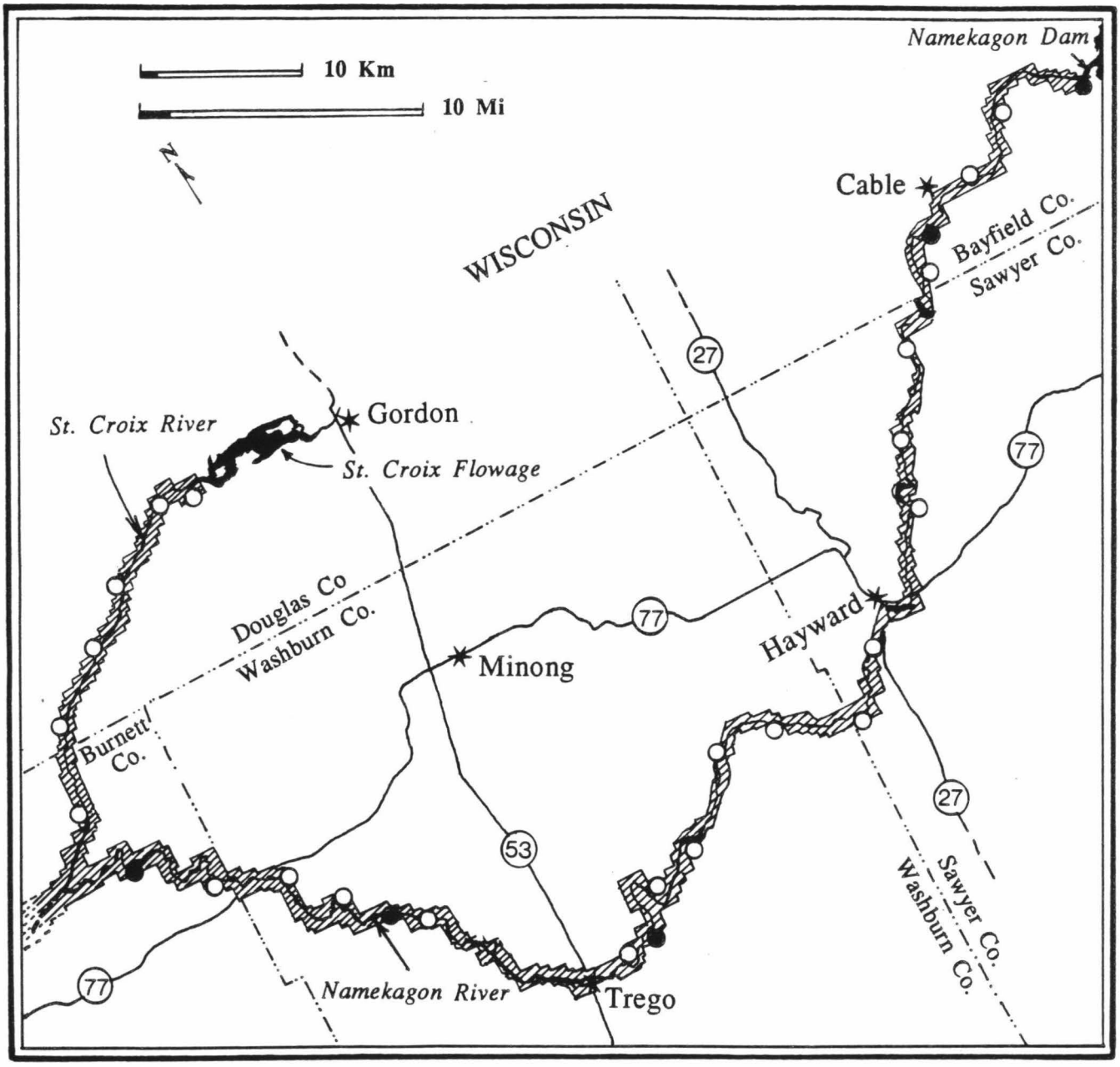

Fig. 5a. Distribution of Lecidea nylanderi (5 localities).

ST. CROIX NATIONAL SCENIC RIVERWAY
Upper St. Croix

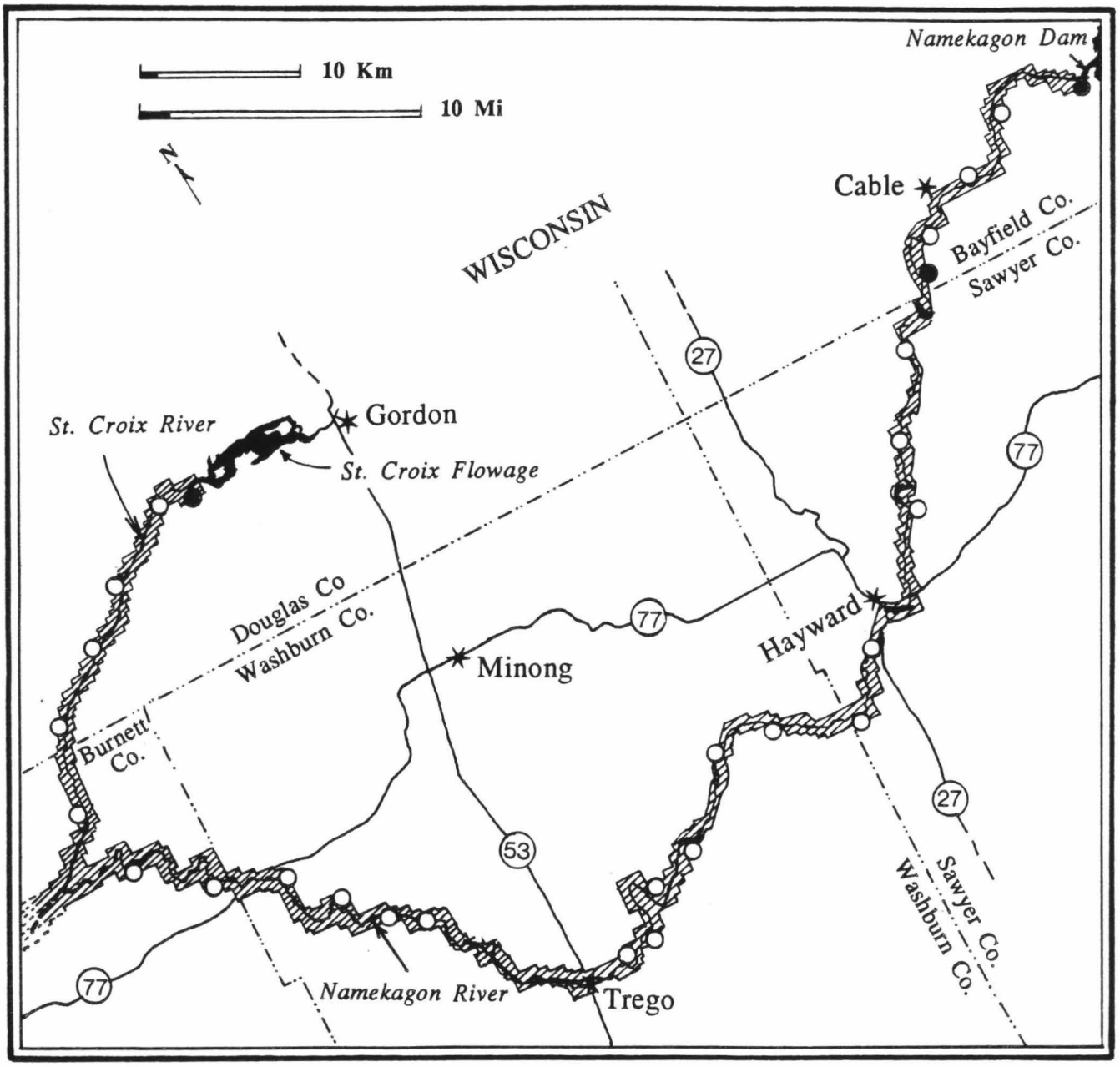

Fig. 6a. Distribution of Lobaria pulmonaria (3 localities).

ST. CROIX NATIONAL SCENIC RIVERWAY
Middle St. Croix

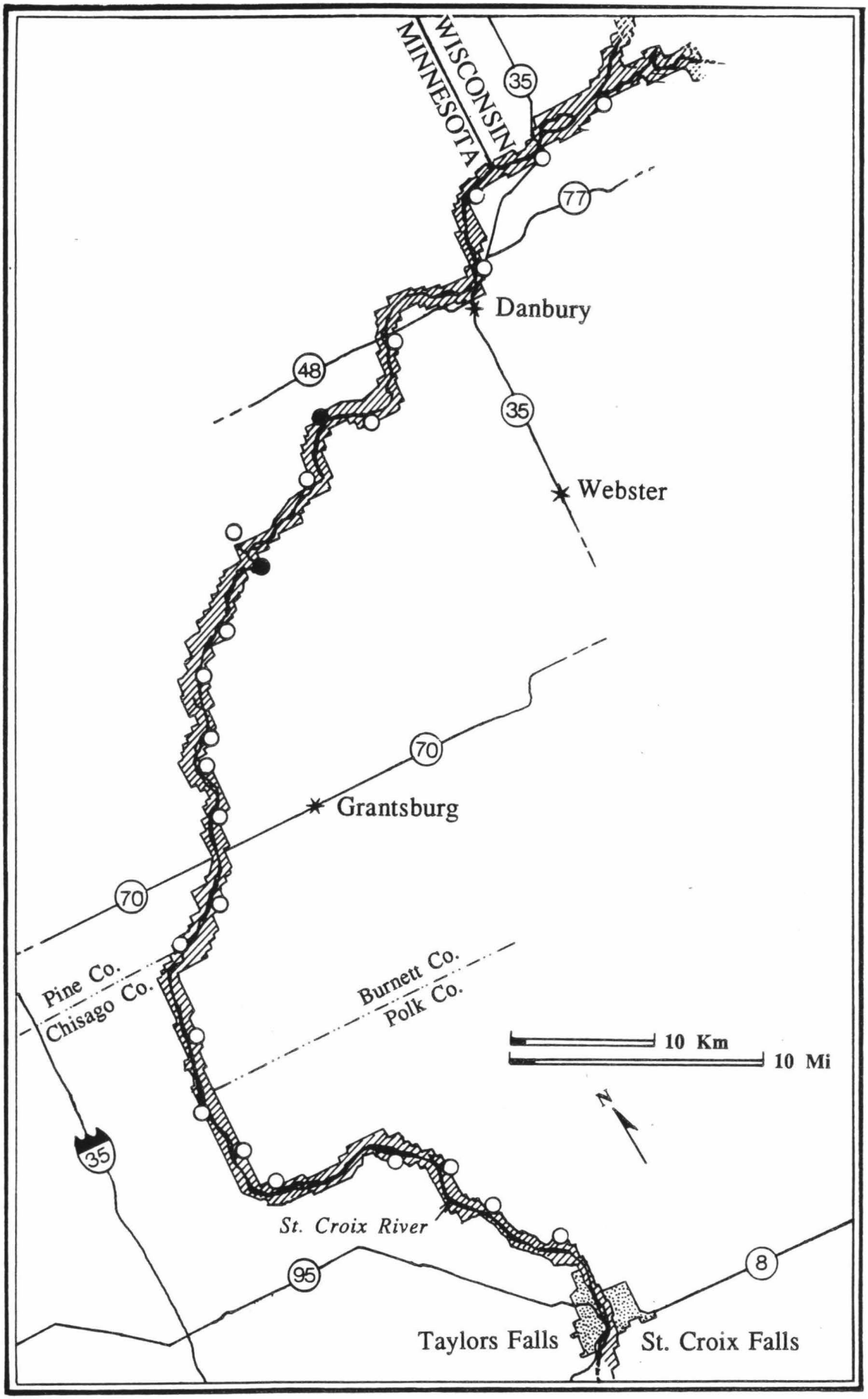

Fig. 7a. Distribution of Ochrolechia rosella (2 localities).

ST. CROIX NATIONAL SCENIC RIVERWAY
Upper St. Croix

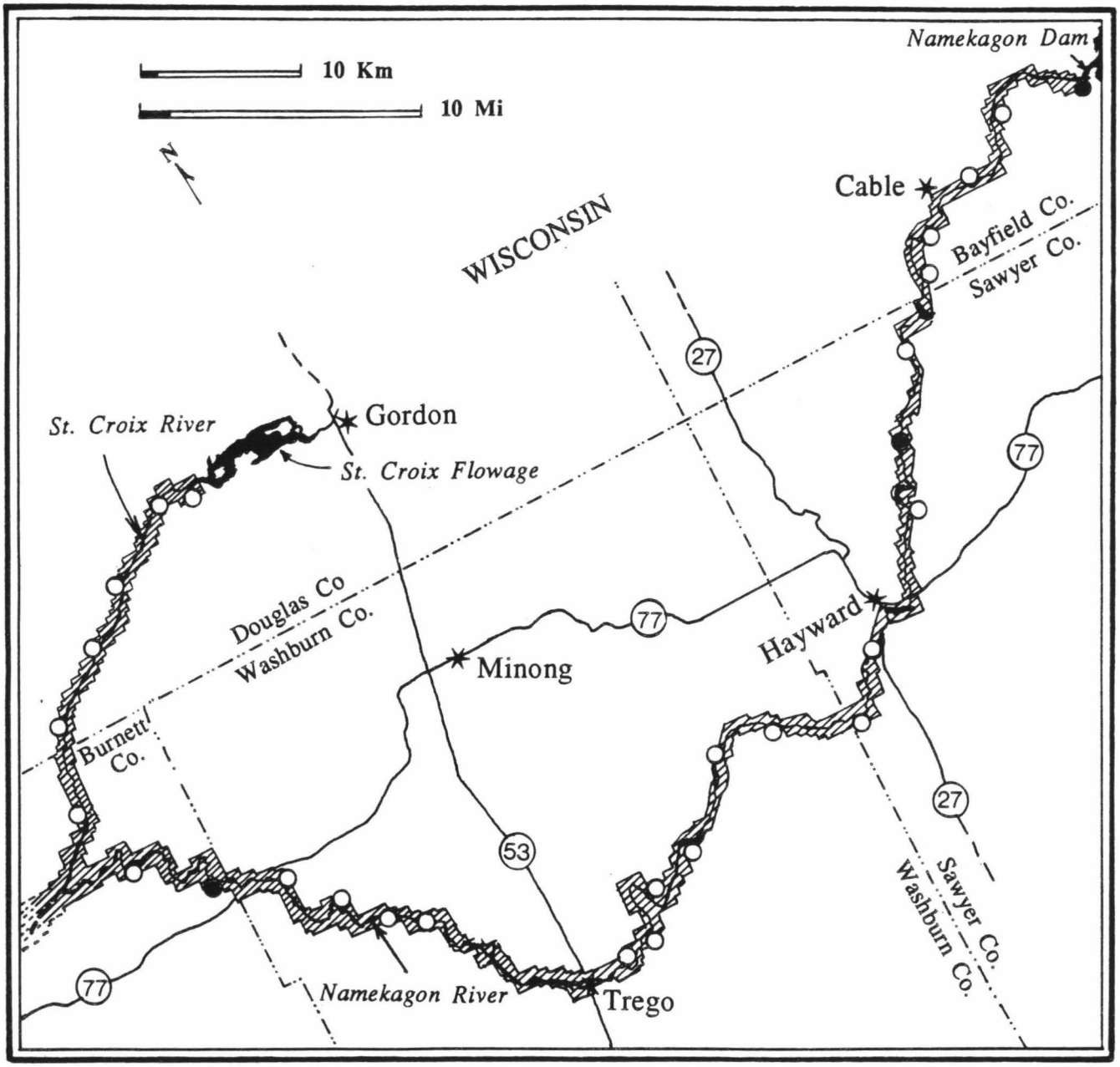

Fig. 7b. Distribution of Ochrolechia rosella (3 localities).

ST. CROIX NATIONAL SCENIC RIVERWAY
Lower St. Croix

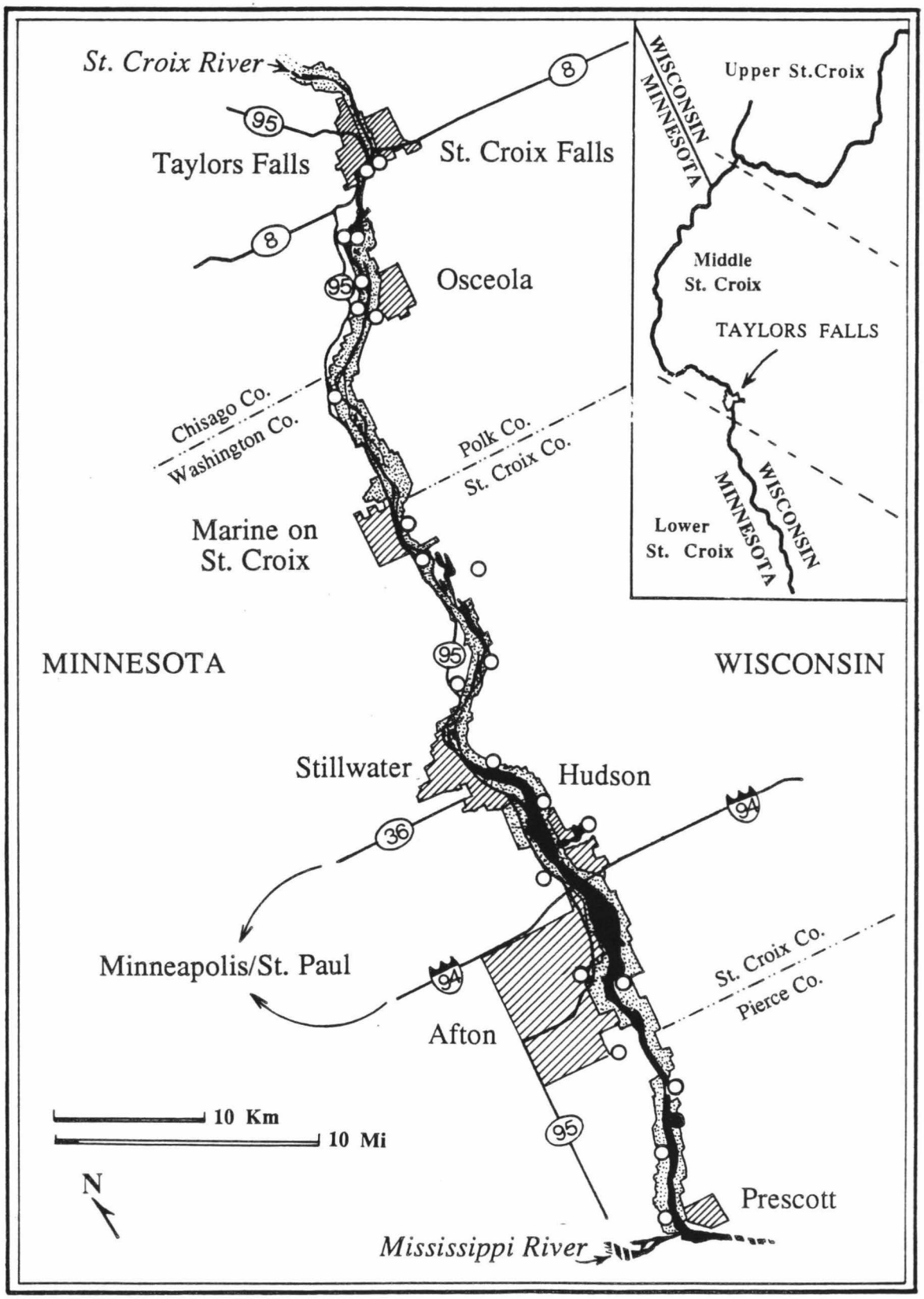

Fig. 8a. Distribution of Parmelia squarrosa.

ST. CROIX NATIONAL SCENIC RIVERWAY
Middle St. Croix

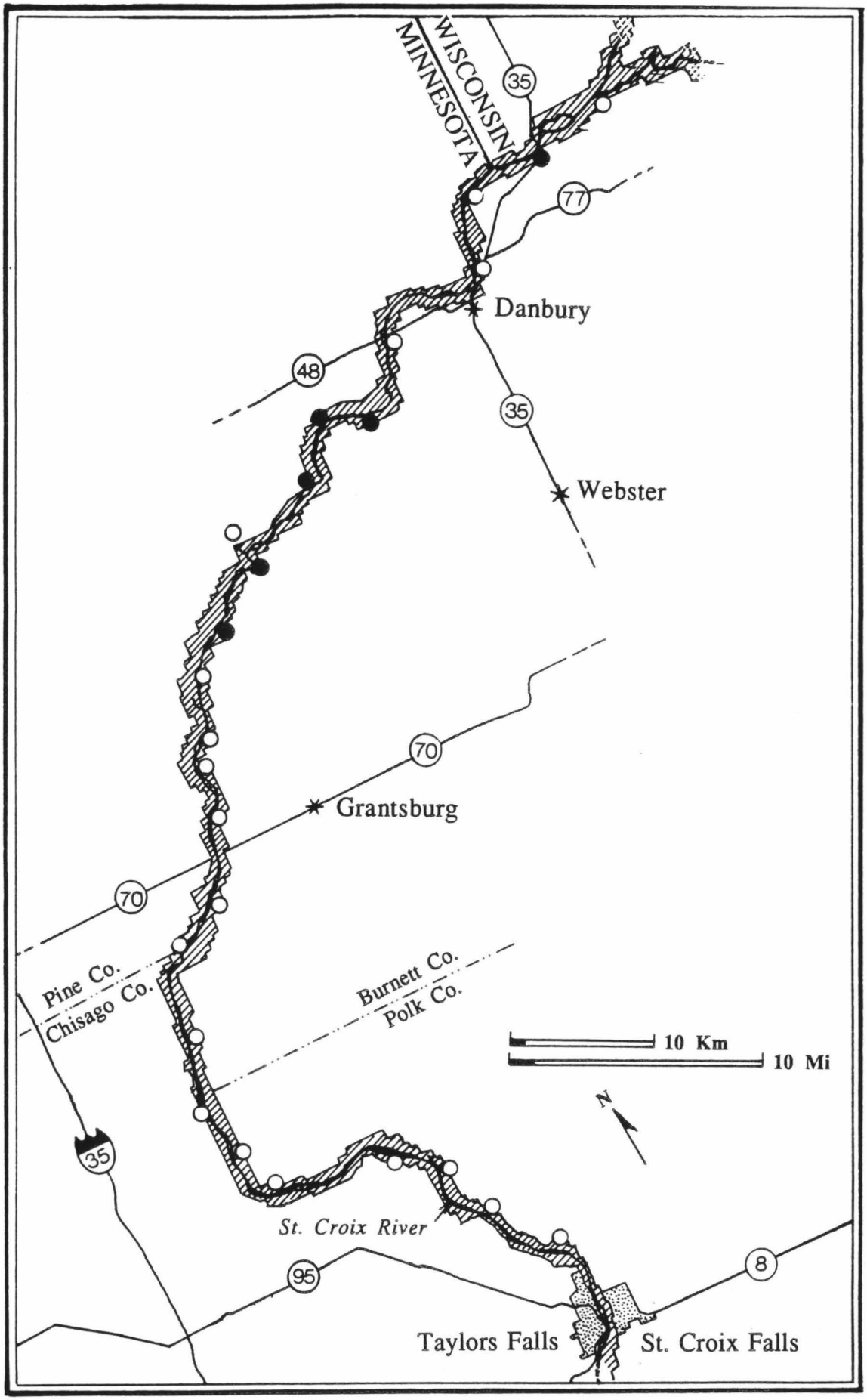

Fig. 8b. Distribution of Parmelia squarrosa.

ST. CROIX NATIONAL SCENIC RIVERWAY
Upper St. Croix

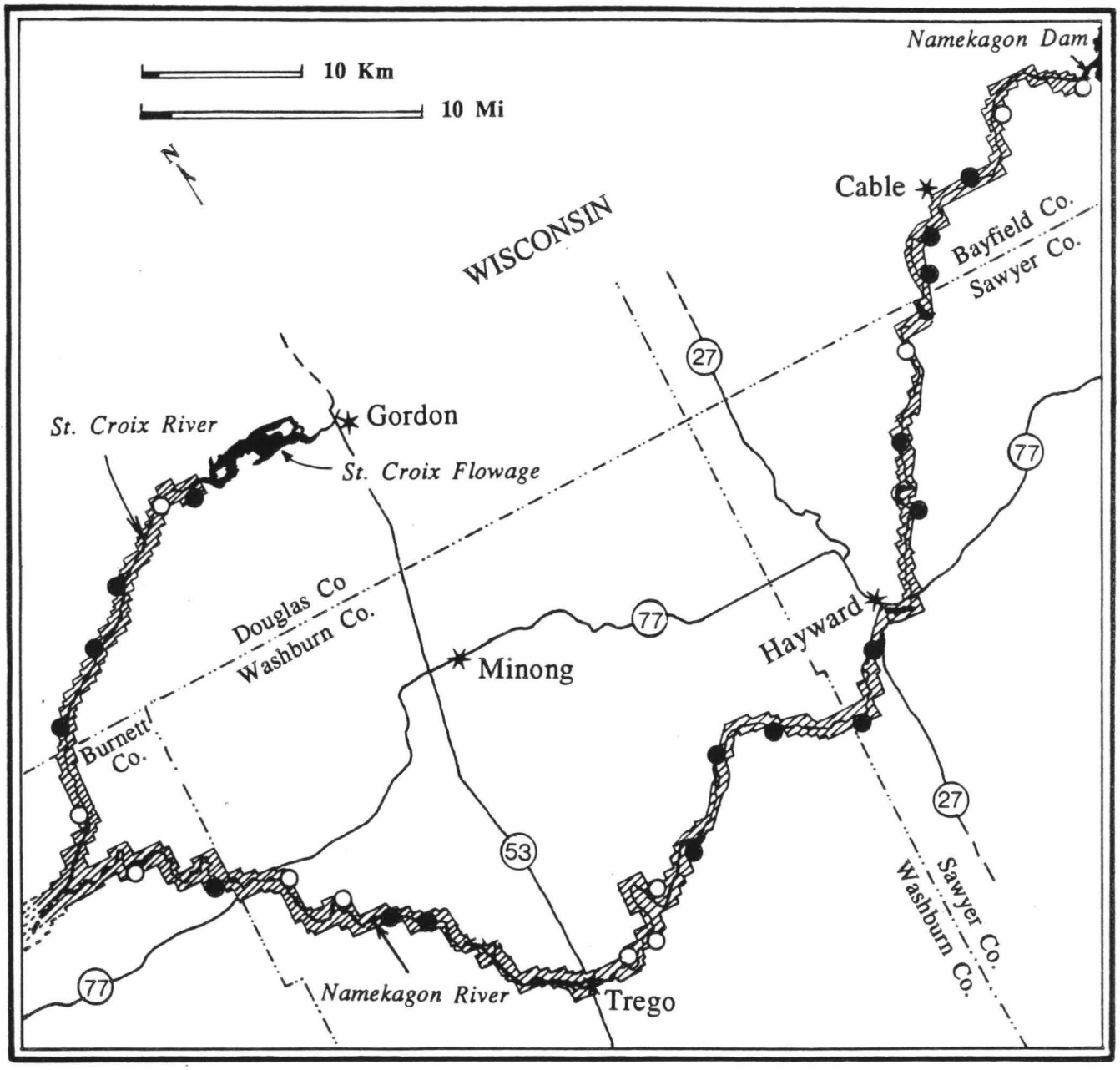

Fig. 8c. Distribution of Parmelia squarrosa.

ST. CROIX NATIONAL SCENIC RIVERWAY
Lower St. Croix

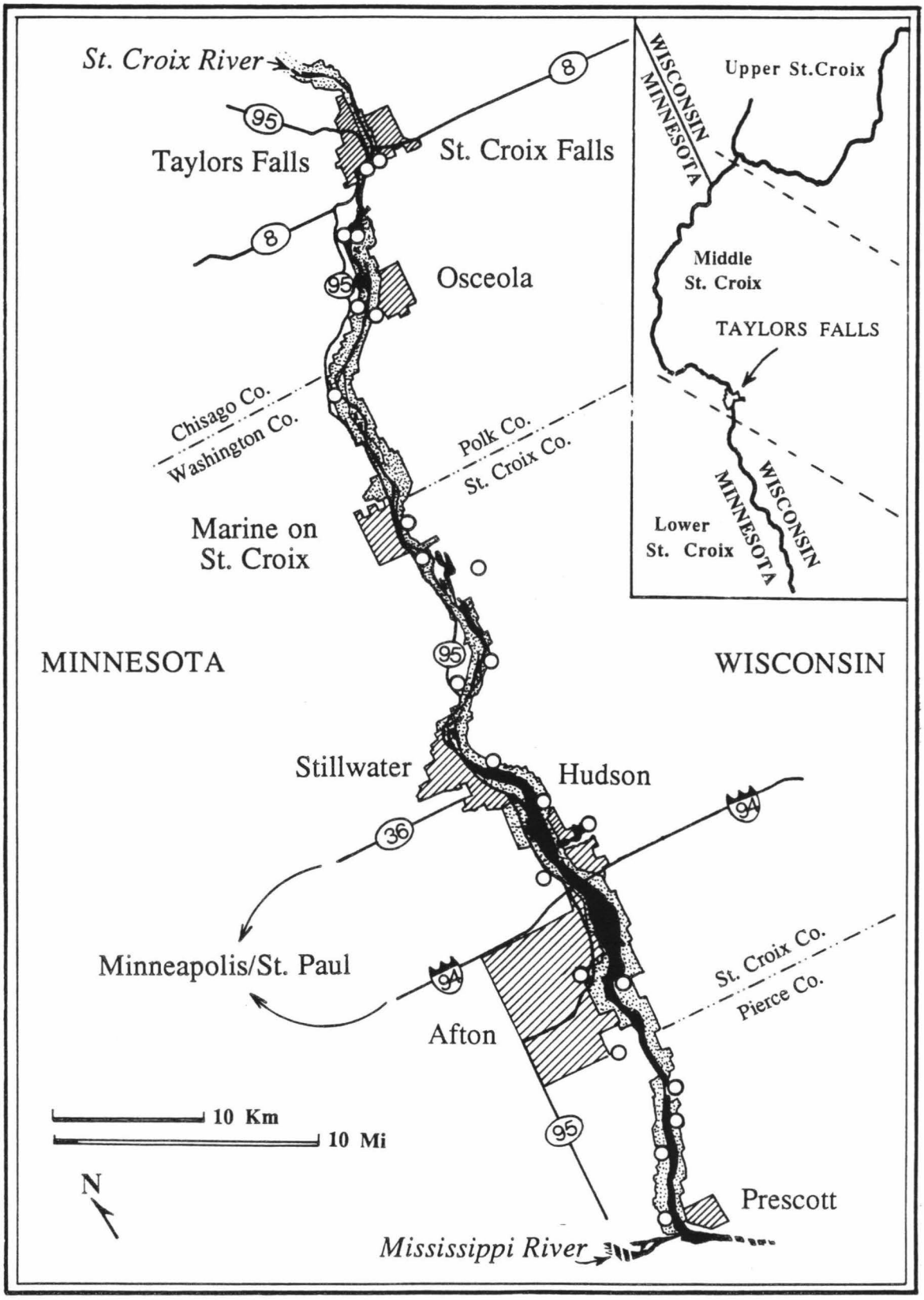

Fig. 9a. Distribution of Ramalina americana.

ST. CROIX NATIONAL SCENIC RIVERWAY
Middle St. Croix

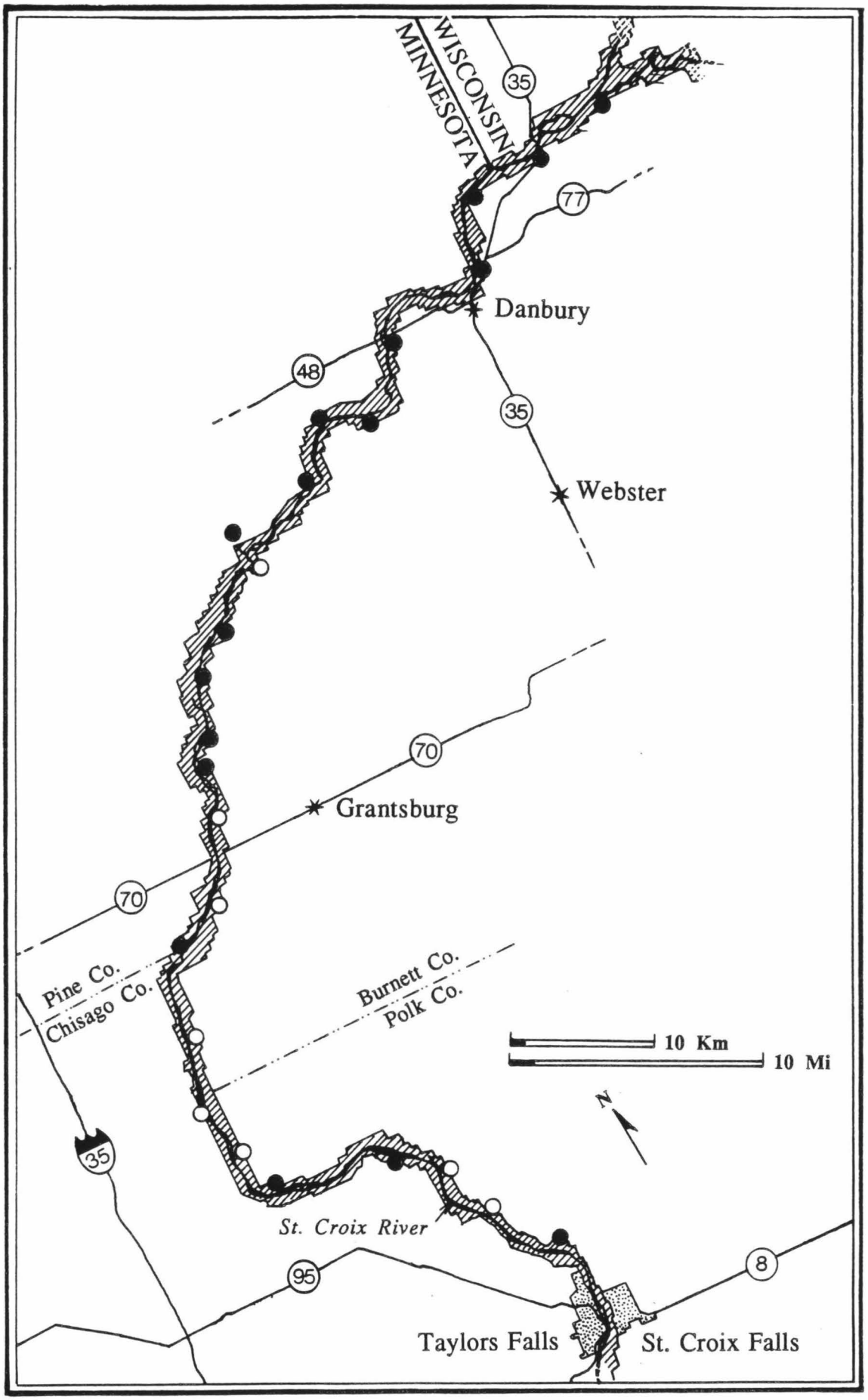

Fig. 9b. Distribution of Ramalina americana.

ST. CROIX NATIONAL SCENIC RIVERWAY
Upper St. Croix

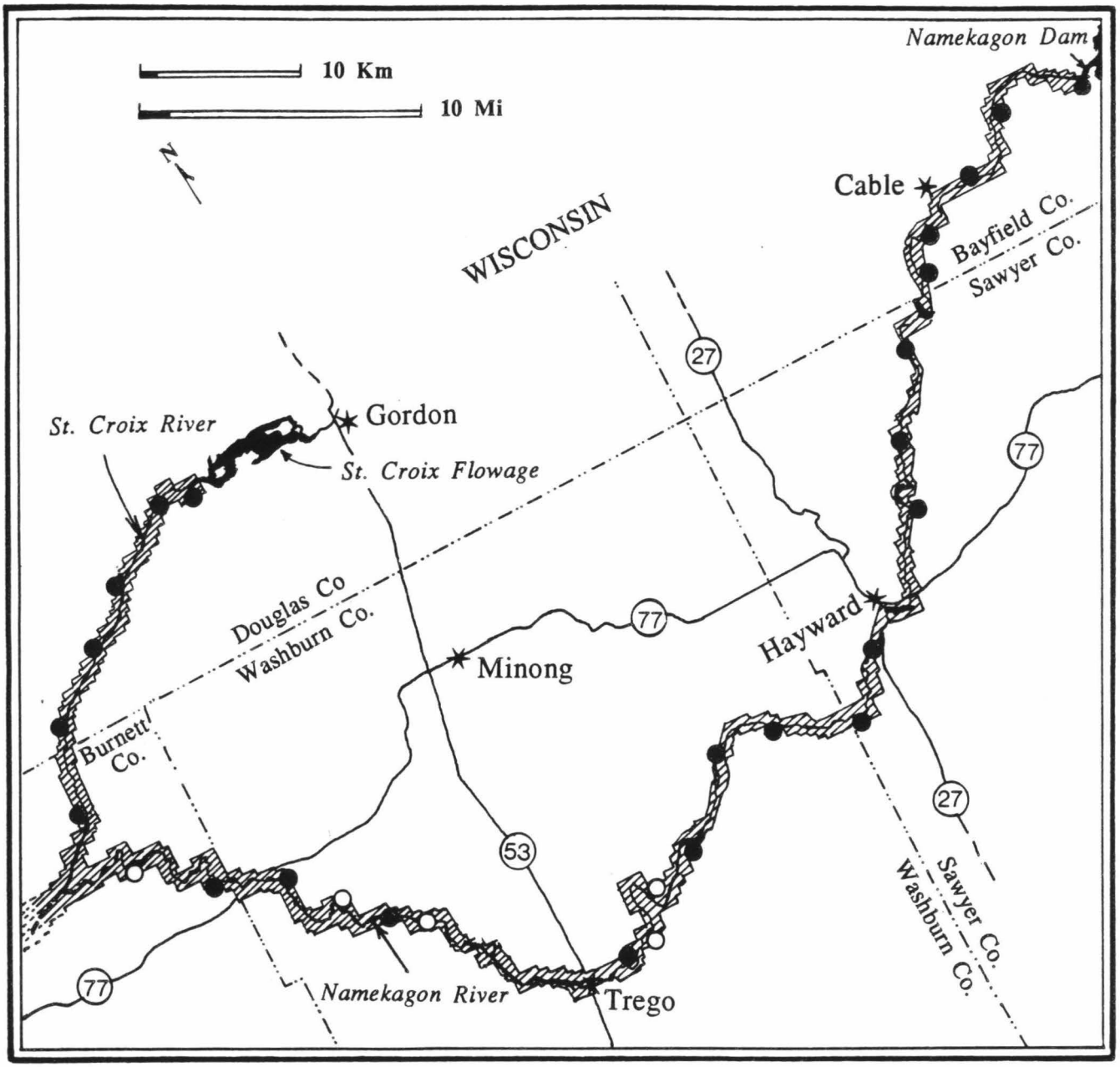

Fig. 9c. Distribution of Ramalina americana.

APPENDIX III

Species Collected by Fink at Taylors Falls (1898).

The taxa reported by Fink are followed by their present identifications based on reexamination of the specimens in the University of Minnesota Herbarium. The numbers are the collection numbers cited by Fink. Fink collected almost exclusively on rocks.

Biatora coarctata var. *brajeriana* 92 = *Trapelia coarctata*
Biatora myriocarpoides 100 = *Lecidea erratica*
Biatora rufonigra 1 = *Psorula rufonigra*
Buellia petraea 58 = *Rhizocarpon grande*
Buellia petraea var. *grandis* 89a = *Rhizocarpon plicatile*
Buellia petraea var. *montagnaei* 89 = *Rhizocarpon grande*
Buellia spuria 22 = *Buellia stigmatea*
Cladonia caespiticia 68a, 101 = *Cladonia caespiticia*
Cladonia cariosa 114 = *Cladonia cariosa*
Cladonia delicata 79a, 67 = *Cladonia parasitica*
Cladonia fimbriata 104, 110 = *Cladonia rei*
Cladonia gracilis 74 = none in MIN
Cladonia gracilis var. *verticillata* 116 = *Cladonia verticillata*
Cladonia macilenta 79b, 80a = *Cladonia bacillaris*
Cladonia mitrula 99 = *Cladonia peziziformis*
Cladonia pyxidata 65 = *Cladonia pyxidata*
Cladonia rangiferina 81 = *Cladina rangiferina*
Cladonia rangiferina var. *alpestris* 82 = *Cladina mitis*
Cladonia squamosa 72, 78 = *Cladonia squamosa*
Collema flaccidum 43 = *Collema subflaccidum*
Collema pulposum 23 = *Collema bachmanianum*
Endocarpon hepaticum 97 = *Endocarpon pusillum*
Endocarpon miniatum 41 = *Dermatocarpon miniatum*
Ephebe solida 59 = none in MIN
Lecanora atra 4 = *Lecanora atra*
Lecanora cinerea 11, 19, 34, 70 = *Aspicilia cinerea*
Lecanora cinerea var. *laevata* 14 = *Aspicilia cinerea*
Lecanora fuscata 33, 56, 94, 106 = *Acarospora fuscata*
Lecanora hageni 118 = *Lecanora dispersa*
Lecanora rubina 51 = *Lecanora muralis*
Lecanora subfusca 12, 115 = *Lecanora cenisia*
Lecanora subfusca var. *coilocarpa* 108 = *Lecanora circumborealis*
Lecanora varia 68 = *Lecanora mutabilis*
Lecanora varia var. *symmicta* 103 = *Lecanora dispersa*
Lecidea albocaerulescens 27 = *Porpidia albocaerulescens*

Leptogium chloromelum 109 = Leptogium cyanescens
Leptogium tremelloides 18, 25, 29, 61 = Leptogium cyanescens
Nephroma helveticum 26 = Nephroma helveticum
Pannaria lanuginosa 20 = Lepraria lobificans
Pannaria microphylla 35 = Pannaria leucophaea
Parmelia borreri 111 = Parmelia rudecta
Parmelia caperata 50 = Parmelia baltimorensis
Parmelia conspersa 49 = Parmelia taractica
Parmelia crinita 66 = Parmelia rudecta
Parmelia olivacea 60 = none in MIN
Parmelia perforata 71 = Parmelia reticulata
Parmelia saxatilis 52, 67 = Parmelia hypoleucites
Peltigera canina 16, 28 = Peltigera rufescens
Peltigera canina var. sorediata 96 = Peltigera didactyla
Peltigera canina var. spuria 119 = none in MIN
Peltigera pulverulenta 15 = Peltigera elisabethae
Peltigera rufescens 17 = Peltigera elisabethae
Pertusaria communis 112 =" Pertusaria pertusa" misident.
Pertusaria velata 95 = Pertusaria velata
Physcia aquila var. detonsa 42, 86 = Anaptychia palmulata
Physcia caesia 30 = Physcia halei
Physcia obscura 5, 47 = Phaeophyscia adiastola
Physcia pulverulenta 73 = Physconia detersa
Physcia speciosa 63 = Heterodermia speciosa
Physcia stellaris 2 = Physcia phaea
Physcia tribacia 55, 77 = Physcia dubia
Placodium aurantiacum 57 = Caloplaca vitellinula
Placodium cerinum 38, 39, 91 = Caloplaca sideritis
Placodium cinnabarina 31, 62 = Caloplaca cinnabarina
Placodium elegans 53 = Xanthoria elegans
Placodium vitellinum 3 = Candelariella aurella
Pyxine sorediata 48 = Pyxine sorediata
Ramalina calicaris var. farinacea 83 = Ramalina intermedia
Rinodina sophodes 59, 105 = Buellia alboatra & B. punctata
Stereocaulon condensatum 93 = Stereocaulon paschale
Teloschistes concolor 102 = Candelaria fibrosa
Teloschistes lychneus 64 = Xanthoria fallax
Thelocarpon prasinellum 113 = Thelocarpon laureri
Umbilicaria dillenii 87 = Umbilicaria mammulata
Urceolaria scruposa 9 = Diploschistes scruposus
Usnea barbata var. florida 45 = none in MIN
Usnea barbata var. rubiginea 117 = none in MIN
Verrucaria fuscella 21 = Verrucaria fuscella
Verrucaria muralis 107 = Verrucaria muralis

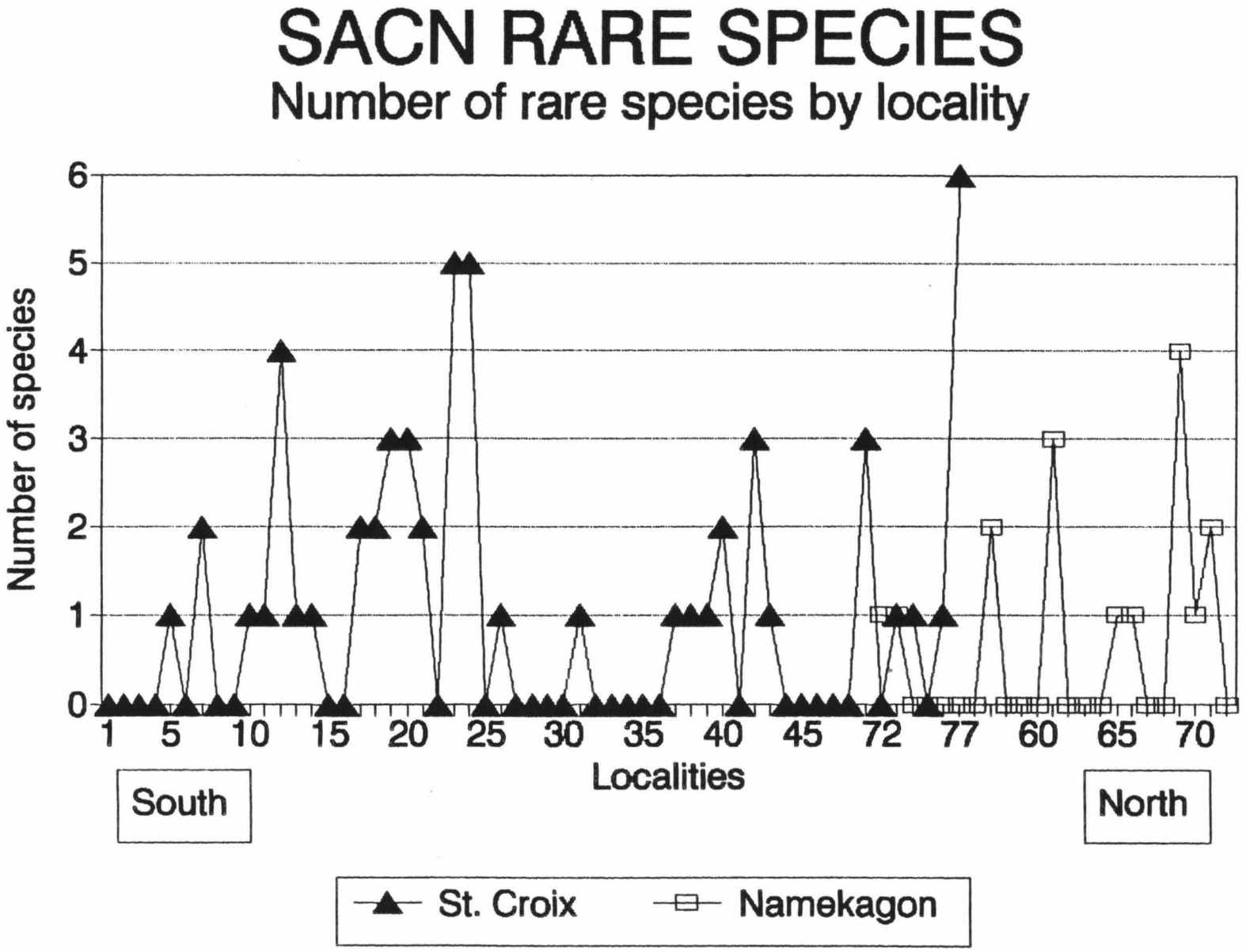

Fig. 10. Number of rare species per locality in SACN

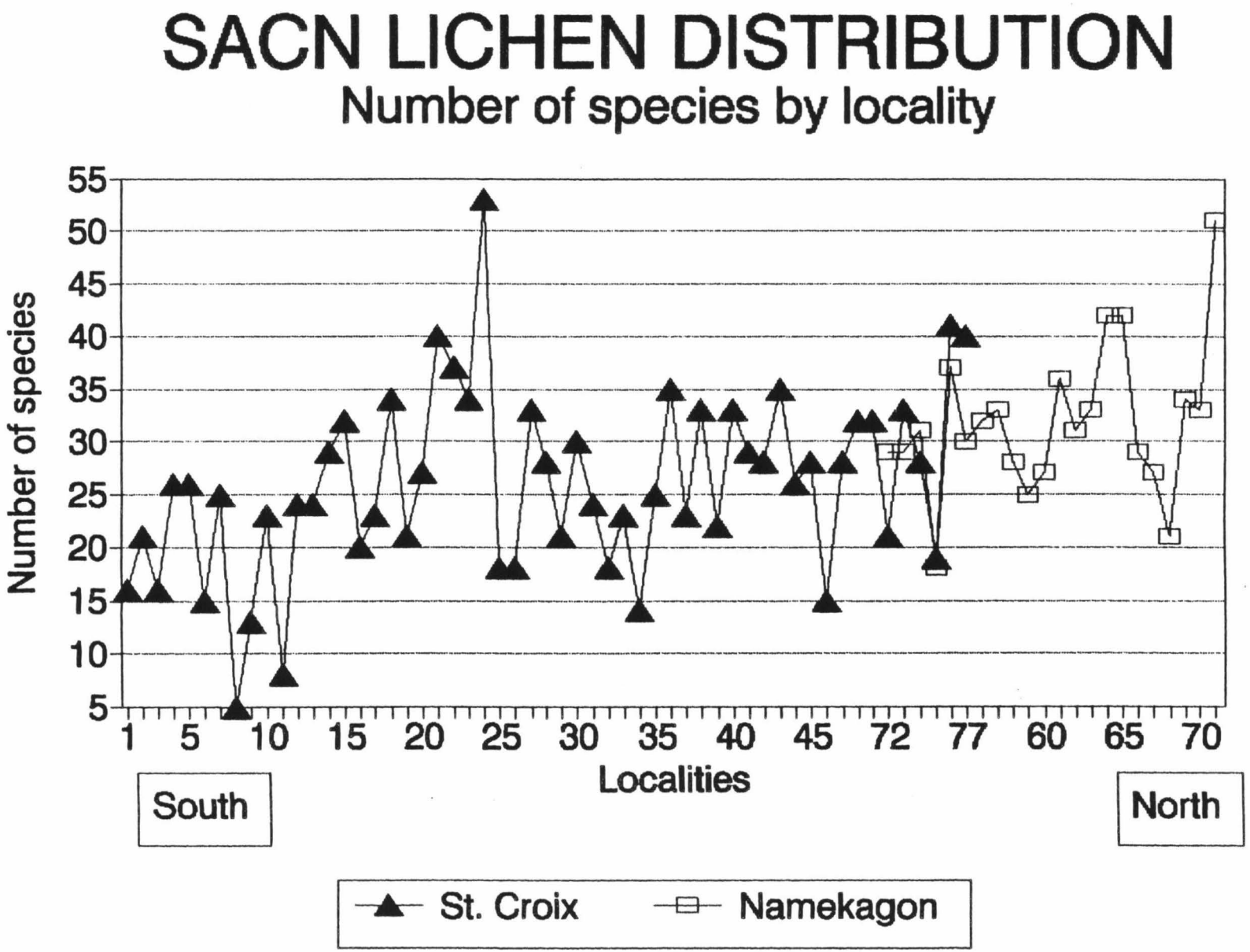

Fig. 11. Number of species per locality in SACN